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WATERSHED CONTROL FOR WATER QUALITY MANAGEMENT

Reginald Bowering, et al

Pollution Control Council
Portland, Oregon

April 1961

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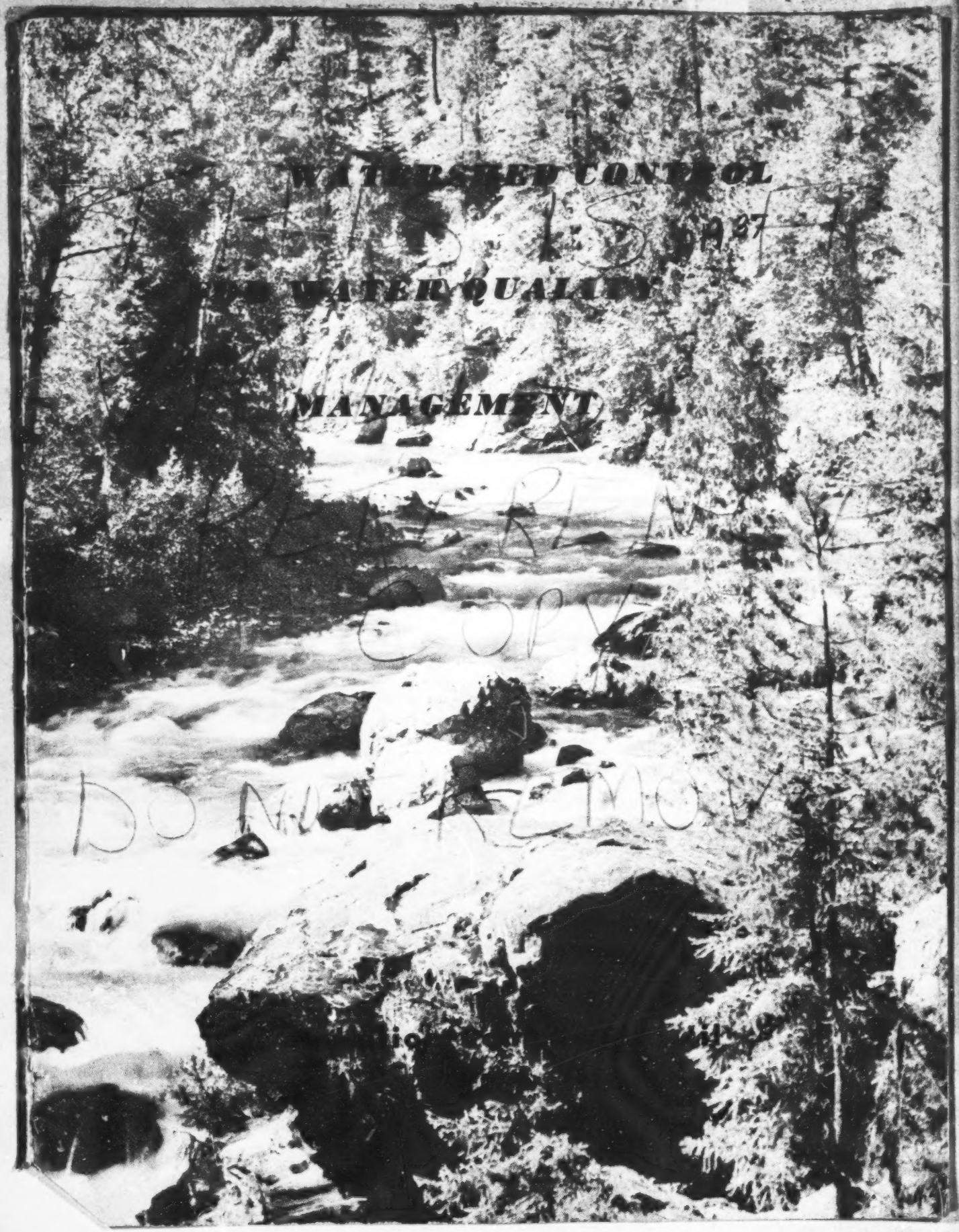
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WATERSHED CONTROL FOR WATER QUALITY MANAGEMENT

By
Committee on Watershed Protection

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POLLUTION CONTROL COUNCIL
Pacific Northwest Area

April 1961

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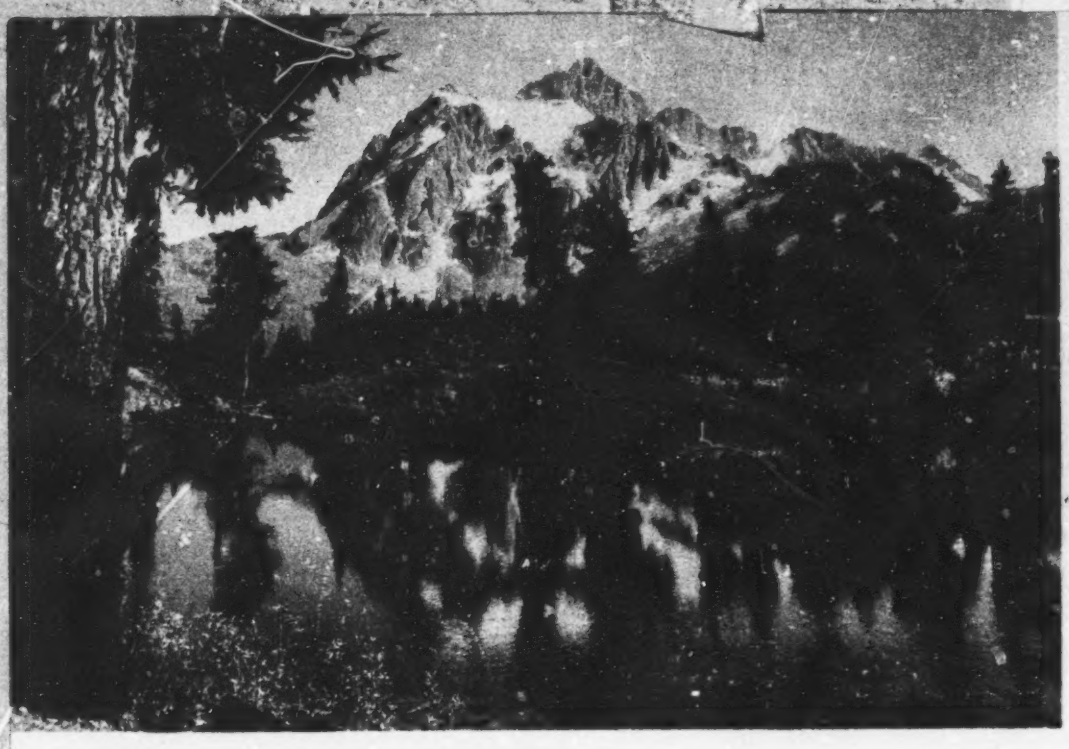

Mt. Shuksan, northwest Washington

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INTRODUCTION

The importance of water quality maintenance is summarized in the REPORT OF THE SENATE SELECT COMMITTEE ON NATIONAL WATER RESOURCES*: "An ample supply of good quality water is essential to the continued welfare of modern civilization ... The nature, the immediacy and the gravity of the water resources problems faced ... vary greatly from region to region, but it is clear that all parts of the country either have or will have problems. In some areas they could become quite painful and have a far-reaching effect on the economy ... Existing withdrawals of water ... will be doubled by 1980 and tripled by the year 2000 if present trends are continued. Even greater ... is the importance of maintaining water quality through pollution abatement in order that increased reuse of water will be possible ... and to improve conditions for recreation and for conservation of fish and wildlife to support increased leisure time activities of the people."

The purpose of this water supply and watershed protection document is to demonstrate the basic principles and problems of long-range programs of water quality protection and management on forested watersheds in the Pacific Northwest. Consideration is given to natural as well as man-caused variations in water resource characteristics and their relationships to municipal, industrial and agricultural consumptive uses and the non-consumptive uses of water including fisheries and recreation. The report summarizes water supply and quality requirements for the various uses in the Pacific Northwest, indicates how lack of adequate control measures and management practices adversely affects these uses, and includes recommendations for improvements in watershed protection and management. Fact-finding inventories, basic data and research and analysis are component parts of such programs.

The area to which this report applies includes the Columbia Basin in the states of Montana, Wyoming, Idaho, Utah, Nevada, Washington, and Oregon, coastal drainages in Oregon, the Puget Sound and coastal drainages in Washington, the Province of British Columbia in Canada, and southeastern Alaska. Since this area covers a wide range of climate, topography, soils, and vegetation, many of the recommendations made herein will undoubtedly apply elsewhere.

This report considers primarily the upper watersheds. It deals with forest, range, and cropland; their various uses, the cultivation and harvest of crops, and other activities having effects on the water which flows from all these lands. It is not concerned with processing of products and associated waste disposal problems of canneries, dairies, meat-packing plants, pulp and paper mills; though these are highly significant in their relation to water pollution, they are outside the province of this manual.

The recommendations included for construction of roads and railroads and for agricultural activities are applicable to the lower as well as the upper portion of watersheds. Some of the watersheds in the Pacific Northwest still are in their virgin state and yield water of high quality; some have been so modified by various activities that their usefulness has been impaired through changes in quality and quantity. Continued economic development will necessitate extending resource developments into the upper reaches of all watersheds and utilizing more extensively the resources in presently developed areas of the Pacific Northwest. In the utilization and development of the land and water resources, Federal and State agencies and private enterprises should consider it their responsibility to: (1) preserve the excellent quality of water where it still exists in nature; and (2) help restore the quality of water in all areas. Demands and needs for water will guide management; correction and control of abuses on the watersheds will permit increasing the diversity of water utilization.

The first of these responsibilities requires proper planning for developing and using the various resources of the watershed. Control measures and practices required on the watershed usually represent only a small part of the cost of development of a particular resource; they are more effective and less expensive when they are an integral part of development. Protection of the water resource, whether by specific control measures on the streams or by proper management practices on the watersheds, must be recognized as a part of any enterprise using or capable of affecting water.

Basic to proper planning is full knowledge of factors controlling water resources. Physical conditions of the watersheds control water yields as to amount, timing, and quality; and to a considerable extent also control the various possibilities for management. Physiographic and climatic characteristics as well as land use and condition are significant factors. This report, therefore, begins with their description.

Water for domestic use obtained from controlled and properly managed watersheds in the Pacific Northwest is being produced with minimal treatment at a cost of about one dollar per million gallons. By contrast, it costs on an average about 40 dollars per million gallons to treat contaminated or turbid waters to produce a less desirable product. Water used for some industrial purposes often requires a greater degree of treatment than that used for domestic purposes. Cool, clean water is essential for growth and propagation of desirable species of fish and shellfish. Clean streams are a major recreational asset of the Pacific Northwest, and enhance land values as well as providing for a tourist industry of national importance.

Public policy will govern to a great extent the efforts to restore waters already damaged by various watershed activities to conditions permitting increased beneficial use. Unfortunately, the economic and physical conditions associated with certain land use practices create problems which may make difficult the restoration of waters to their original quality. It is feasible, however, in most cases where water quality is still adequate to use prevention and control measures and management practices recommended in this report and thereby to avoid more expensive programs of correction at a later date. The cooperative efforts of Federal and State agencies with private enterprise are essential.

Determining the responsibility and securing compliance for correction of conditions that adversely affect the quality of water from a watershed may pose special problems in the case of abandoned mines and on completed logging operations and road construction. Proper control may require new legislation where State, Province, or Federal laws are not adequate to assign responsibility or to require the present landowners to correct conditions.

* Report No. 29, 87th Congress, 1st Session, January 30, 1961. Pursuant to S. Res. 48, 86th Congress

Undisturbed mountain watersheds produce high-quality water

A forested mountain watershed with logging and access roads, a dam and reservoir, recreation opportunity, and urban developments -- a typical water use and watershed management complex.

Physical Features of Northwest Watersheds

PHYSIOGRAPHY

The Pacific Northwest is characterized by three north-south chains of mountains that control the major topography and the climate. The first mountain chain on the west, immediately against the Pacific Coast, begins in the Siskiyou (Klamath) Mountains on the south, includes the relatively low coast ranges in Oregon, the Willapa Hills in southwestern Washington, the high block of the Olympics in northwestern Washington, the mountains of Vancouver Island, and the coast ranges of British Columbia and southeastern Alaska. The second mountain chain includes the Cascade Ranges which extend north from the Siskiyou and Klamath cross-ranges to southwestern British Columbia where they join the coast ranges. On the east the Rocky Mountains of Wyoming, Idaho, Montana and British Columbia form the rim of the area. In addition, the Bitterroot Range, a western outlier of the Rockies between Montana and Idaho, and its Canadian extension, the Selkirk Range, also are a prominent feature of the region.

The Pacific Northwest comprises several major physiographic provinces. According to Fenneman*, they are: Northern Rocky Mountains, Rocky Mountain Trench, Okanogan Highlands, Columbia Plateau (including the Blue Mountains and Wallowa Mountains), Snake River Plain, the Great Basin portion of south central Oregon, the Sierra-Cascade Ranges, Puget Sound-Willamette Trough, Coast Ranges, and British Columbia Plateau. On the north in British Columbia and Alaska the Coast Ranges and the Cascade Ranges are more or less united into one province. For purposes of this report the southeastern Alaska Panhandle, the Kenai Peninsula, Kodiak Island, and the Alaska Peninsula (more or less the first and third judicial districts) are considered part of the Northwest.

Elevations range from sea level to more than 20,000 feet (on Mt. McKinley in Alaska). Geologically the mountains

* Physiography of Western United States, by N. M. Fenneman McGraw Hill, 1931

of the region are comparatively young and their topography is rough. Streams flowing from the mountains generally occupy steep-walled canyons on gradients that permit rapid flow. In the plateau provinces topography is less rugged and the streams flow more slowly.

The shape and width of the valleys affect both the type and extent of use and development, and therefore also affect the population and the actual and potential pollution contributions. The Puget Sound-Willamette Trough, the Columbia Plateau, and the Snake River Plain are the areas of greatest agricultural and industrial development and settlement.

GEOLOGY

Rock formations of the area are grouped more or less by physiographic provinces, though a single province may include several different rock types. The Coast Range province in southern Oregon includes sandstones and other sedimentaries, metamorphic peridotite and serpentine and shale. To the north it includes old volcanic basalts and breccias, sandstones and conglomerates. The Olympic Mountain block includes marine sedimentaries and slates. The Cascades include a variety of volcanics in the center and to the south, but on the north include granites, diorites, metavolcanic greenstones, and sedimentaries as well. The Okanogan Highlands are made up of older intrusive granites, greenstones, and sedimentaries, and recent glacial drift. The Columbia Plateau province is largely made up of volcanics, mainly basalts, covered in many areas with glacial drift or fine windlaid materials and alluvium. In Oregon much of the windlaid material is pumice. The Great Basin and the Snake River Plain are predominantly volcanic. The Puget Sound-Willamette Trough comprises mainly compressed glacial sediments on the north and alluvium on the south. The Rocky Mountain ranges are a mixture of intrusive granites and diorites, various metamorphic rocks, and sedimentaries. A wide range in water quality may be observed in the waters produced in these different areas. Geology is often reflected in the amount and composition of sediment in the streams, or in the minerals in solution.

CLIMATE

Precipitation is the principal climatic element concerned in the water resource. In the Pacific Northwest, precipitation (including both rain and snow) generally increases from south to north, from east to west, and from valleys to mountains. The general movement of storms is easterly from the Pacific Ocean. The Coast Ranges of Oregon and Washington, the Olympics, the mountains of Vancouver Island, and the coastal mountains of British Columbia and southeastern Alaska lie across the storm path and intercept much of the atmospheric moisture. Annual precipitation varies from 70 inches on the southern end of the coastal ranges to more than 150 inches on the north. Going inland eastward from the coast, precipitation decreases in the Puget Sound-Willamette Trough, increases again in the Cascades, drops very low in the arid central Oregon and central Washington valleys and plateaus, and rises again in the Okanogan Highlands and Rocky Mountain provinces.

Snow is an important element of precipitation over most of the region. Mountain snowpacks furnish much of the summer streamflow in the larger rivers. Except in the Olympic Mountains there is little snow storage in the Coast Ranges in Oregon and Washington; but the Cascades and the coastal ranges of British Columbia and Alaska receive and hold a tremendous snowpack. Measurements at middle elevations - 5000 to 6000 ft. - indicate average snowdepths of about 10 feet in the Cascades at the beginning of the spring melt period. Snow accumulates over the period December through March, and the melt occurs mainly over the period April through July.

West of the Cascades the bulk of the precipitation occurs from October to May. Summers are rather dry. In the interior and eastern parts of the region the precipitation is scattered more evenly through the year, with summer convectional storms contributing a significant portion. During storms, particularly in winter and spring, principal wind movement is from the west and southwest. In clear weather it is from the north or east. Strong winds are common along the coast in winter.

Temperatures are moderate in coastal areas where, because of the marine influence, there is little frost in winter and few hot days in summer. In the interior the climate becomes continental in character with cold winters and hot summers, the winter being longer and the summer shorter at higher elevations. Temperatures may range from 50°F to 110°F. Along the coast, the frost-free growing seasons average about 250 days, in the Puget Sound-Willamette Trough about 200 days, on the Columbia Plateau from 140 to 180 days, in the Great Basin 80 to 100 days, and in the Snake River Plain 100 to 160 days.

Streamflow throughout the region drops fairly low in summer and stream temperatures increase. Taste, odor, and color problems develop in many streams during the low flow period because of organic matter leached from soil and humus or from algal blooms.

SOILS

The soils of the Pacific Northwest vary as widely as the parent rocks and the climatic conditions under which they developed. In the coastal and other high rainfall areas the volcanic rocks have produced shot loam to clay loam soils, while the sedimentary and metamorphic rocks have produced sandy loams, clay loams and clays. Sandy loams have developed on the granites and diorites. The Great Basin and Snake River Plain areas have large areas of loose coarse pumice soils. Fine silt loams have developed on the loessial deposits of the Columbia Plateau. Valley alluvium and glacial deposits have soils ranging from loams to clays. Drainage in the compressed glacial drift soils around Puget Sound is usually poor. Both valley and mountain areas have scattered bodies of peat and muck soils high in organic matter.

Erodibility of the soils, their infiltration characteristics, and their ability to withstand use are important to the water resource. Fine-grained readily eroded soils add much sediment and turbidity to streamflow. Loam soils of open texture permit water to infiltrate rapidly and release it slowly to streamflow. Clay soils when wet slide easily, and often may add huge quantities of sediment to streams. Each of these soil types may present a special problem with respect to water quality variations. Classification of soils provides a necessary guide to management of land uses that affect soil conditions.

COVER VEGETATION

Plant cover in the Pacific Northwest varies from dense spruce rain-forest along the coast to alpine heath, from park-like stands of pine to sagebrush desert east of the Cascade Ranges. Broad cover types are associated with climatic variations, particularly precipitation. The wetter areas are forested; the less wet valleys support mixed woodland and grass; the dryer Columbia Plateau is covered with grass and sagebrush; and the arid Great Basin and Snake River Plain have open sparse stands of desert shrubs and ephemeral herbs.

Land use has greatly affected the composition of the cover. Most of the valley areas and the loessial soils of the Columbia Plateau are cultivated. The interior grasslands have

been heavily grazed, and have been invaded by sagebrush and other semi-desert shrubs. Brush has replaced forest in some areas that have been logged and burned repeatedly.

The cover is important to the water resource because the vegetation mass affords certain controls on water movement. The vegetation cover is also itself a consumer of water. Its major value to the water resource is in keeping the soil in condition for rapid infiltration and storage of surface water from rain and snowmelt, and in protecting the soil against erosion.

Specific description of cover types, extent of each type, and its location is given under the section on Land Use and Management.

STREAMFLOW AND WATER SUPPLY

The water resource is available either at ground surface in lakes and streams and springs or by wells from the underground water. Frequently it is the same body of water permeating the earth's rock and soil mantle that makes up both sources, though surface and underground waters are sometimes considered legally separate. Certainly they differ in their accessibility for use and susceptibility to pollution.

Precipitation is a major factor in controlling water yield. But many streams derived from areas having plenty of water flow through arid sections and thus afford them a much needed water supply. The Yakima River in central Washington is a prime example in point.

Water yields of representative streams of the region are shown in Table I. It is interesting to note that the Hoh River with a 78 square mile watershed on the west side of the Olympic Mountains yields just about as much water as the John Day River with a 7,580 square mile watershed in arid eastern Oregon.

TABLE I. YIELD OF TYPICAL NORTHWEST STREAMS

STREAM	Drainage	Average	Average Annual Yield		Minimum Flow	Maximum Flow
			Total	Depth per Unit Area		
	sq. miles	cfs	acre-feet	inches	cfs	cfs
Alaska						
Manzanita Creek	34	465	334,000	185	90	4,480
Harding River	95	710	513,000	101	220	9,900
British Columbia						
Fraser River at Hope	78,300	92,600	67,000,000	16	12,000	536,000
Capilano Creek	76	700	509,000	125	25	23,600
Skeena River at Usk	15,000	29,800	21,600,000	27	1,830	330,000
Columbia River at Birch Bank	34,000	70,540	51,070,000	28	8,940	370,000
Sproat River (Vancouver Island)	128	1,320	955,000	140	50	10,900
Washington						
Lewis River	731	4,730	3,427,000	88	0 1/	129,000
Hoh River	208	2,005	1,450,000	131	250	38,700
Skagit River	3,060	16,170	11,710,000	72	2,740 1/	144,000
Yakima River	3,650	3,840	2,780,000	14	0 1/ 2/	65,000
Methow River	1,330	1,315	952,700	13	130	40,800
Oregon						
Willamette River at Salem	7,280	23,280	16,850,000	44	2,470	500,000
Siletz River	202	1,600	1,159,000	108	50	37,000
Umpqua River	3,680	7,450	5,394,000	27	640	218,000
John Day River	7,580	2,020	1,463,000	4	0 2/	39,100
Owyhee River	11,160	850	614,000	1	0 1/ 2/	22,900
Grand Ronde River	2,555	2,115	1,531,000	11	225	19,900
Idaho						
Snake River at King Hill	35,800	10,530	7,610,000	4	1,250 1/ 2/	47,200
Clearwater River	9,570	15,200	11,000,000	22	500	177,000
Salmon River	13,550	10,910	7,899,000	11	1,580	120,000
Montana						
Bitterroot River, West Fork	317	295	213,000	13	0 1/ 2/	4,060
Flathead River	7,096	11,490	8,304,000	22	5 1/	82,800
Columbia River at The Dalles	237,000	195,300	141,400,000	11	35,000	1,240,000

1/ Regulation from reservoirs upstream
2/ Irrigation diversions upstream

Data drawn from U. S. Geological Survey Water Supply Papers, and Canadian Government Records.

Patch cutting without excessive soil disturbance and with good regeneration for a new timber crop does not upset streamflow or water quality

Land Classification, Use, and Management

LAND TYPES

The United States section south of the British Columbia border amounts to 176,322,000 acres, of which 1,800,000 acres are water surface, with 174,522,000 acres of land. The land area is classified as follows:

Forest land		84,555,000 acres
Non-forested range land		64,258,000 acres
Cropland:		
Irrigated		4,105,000 acres
Non-irrigated		14,421,000 acres
Other (barren, urban, road, etc.)		7,183,000 acres
	Total	174,522,000 acres

For British Columbia, the classification is as follows:

Non-commercial forest land		18,457,000 acres
Forest land, commercial		118,226,000 acres
Non-forested range land		5,000,000 acres
Cropland: 1/		1,148,000 acres
Pasture and forage	(608,000 acres)	
Irrigated 2/	(150,000 acres)	
Non-irrigated	(410,000 acres)	
Not now in use	(180,000 acres)	
Barren (rock, icefield, etc.)		82,870,000 acres
Water		4,500,000 acres
Other (urban, road, etc.)		4,202,000 acres
	Total	234,403,000 acres

Note: 29% of British Columbia lies in Arctic drainage basins.

For southern 3/ Alaska, the classification is as follows:

Non-commercial forest land		12,239,000 acres
Forest land		4,269,000 acres
Non-forested range land		160,000 acres
Cropland and pasture		84,000 acres
Water		300,000 acres
Other (barren, etc.)		18,917,000 acres
	Total	35,969,000 acres

1/ 4,702,000 acres estimated total potentially arable.
2/ 500,000 acres estimated total potentially irrigable.
3/ Here defined as the Panhandle east of Mt. St. Elias, the Alaska and Kenai Peninsulas, and Kodiak Island; comprising the First and Third Judicial Districts.

In summary, approximately 40% of the total area of the region is forest, 15% is non-forested range, and 30% is barren rock, icefield, or other wild land. The forest and high-elevation barren areas are the areas of greatest water yield. What happens in the use and development and management of these lands is of prime importance to the water resource.

Forest. Forest types, as characterized by their principal component species, occur as follows according to U. S. Forest Service and British Columbia Forest Service sources:

Forest Type	Columbia Basin States	British Columbia	Southern Alaska
Interior spruce	--	54,140,000	--
Spruce - Hemlock	2,531,000	9,567,000	4,263,000
Western red Cedar	198,000	8,961,000	--
Douglas fir	30,471,000	15,178,000	--
Ponderosa pine	17,000,000	1,655,000	--
Lodgepole pine	9,100,000	21,108,000	--
Mixed conifer	7,500,000	--	--
White pine	4,000,000	--	--
Non-commercial	12,055,000	18,457,000	12,239,000
Juniper	600,000	--	--
Hardwoods	1,100,000	7,616,000	6,000
Total	84,555,000	136,682,000	16,508,000

The spruce-hemlock type, containing Sitka spruce, western hemlock, and grand fir, is found along the immediate coast throughout the region. The western red cedar is found on wetter sites in the same area, and to some extent further inland mingled with the Douglas fir. The Douglas fir, the principal commercial timber type, is dominant in the Coast Ranges, the Puget Sound-Willamette Trough, and the west side of the Cascade Range to middle elevations. Douglas fir is also a major component of mixed conifer types in the colder and drier interior Okanogan Highland, Columbia Plateau, and Rocky Mountain provinces, but in these areas is not so desirable a timber tree. Ponderosa pine is the principal commercial timber type of the interior, from the east side of the Cascade Range to middle elevations of the Rocky Mountains. Lodgepole pine is found in a few places along the coast, but is primarily on the

higher slopes of the east side Cascades, the Okanogan Highlands, the British Columbia Plateau, the Rocky Mountains and the Blue-Wallowa mountain block of the Columbia Plateau. White pine as a type is found in the northern Rocky Mountain area. The mixed conifer type may contain Douglas fir, western hemlock, mountain hemlock, various true firs, white pine, larch, Engelmann spruce (and white and black spruce in northern British Columbia and Alaska), and a few other conifers in various mixtures, and usually occupies the higher mountain slopes throughout the region. Much of the non-commercial forest is mixed conifer type that is too sparse or too stunted and poor in quality to harvest. The non-commercial areas are found on both the upper and lower fringes of the forested area, but the bulk of it is at the higher elevations. Juniper is a semi-desert type found mainly in central and southern Oregon and southern Idaho on the fringes of the Columbia Plateau and Snake River Plains provinces. Hardwoods include several species: oaks, alders, cottonwoods, maples, and birches for the most part. The oaks are found in the valleys and foothills, the alders and cottonwoods and maples in the wetter sites along streams throughout the region at all elevations, and the birches throughout the colder northern areas of British Columbia and Alaska around Cook Inlet.

These forest types are one of the major resources subject to economic development in the region. Timber for lumber, veneer, and other structural purposes comes from the Douglas fir, ponderosa pine, mixed conifer, and white pine types. Pulpwood is taken for the most part from the coastal spruce-hemlock and the mixed conifer types, though considerable amounts also come from the Douglas fir type, and a little from the hardwoods. Cedar is used for shingles, posts and poles. Lodgepole pine is now being used in hardboard manufacture. Some hardwoods are used in making furniture.

Agricultural Land. Recent cropland use is as follows, according to U. S. Department of Agriculture and British Columbia government sources:

Agriculture is another major segment of the economy of the region. Principal agricultural products include wheat and other grains, apples, peaches, peas, sugar beets, potatoes, nuts, berries and truck crops. There is a sizeable dairy and poultry industry. Livestock, including more than four million cattle, about three million sheep, and a half a million hogs are also raised on the farms and range lands.

Major agricultural areas include the narrow coastal strip and valley mouths in Oregon, Washington, and British Columbia, the Puget Sound-Willamette Trough, the valleys of the east side of the Cascades and the Okanogan Highland, the Columbia Plateau except for the high mountainous parts, the Snake River Plain, and the valleys of the Rocky Mountains. The Columbia Plateau and the Snake River Plain contain the principal areas of irrigated land, though irrigation is increasing in the Puget Sound-Willamette River Trough.

Range Land. Range land is ordinarily classified separately from pasture on the basis of treatment, pasture being cultivated, fertilized, seeded, and irrigated. More and more range land, however, is being given such treatment, though generally less intensively and less regularly than that given pasture.

The range land in the Columbia Basin states includes 64,258,000 acres of non-forested open land, plus about 70 per cent of the land already classified as forest for an additional 59,200,000 acres. The high elevation summer ranges are characterized by open grassland, perennial weeds, and shrub browse, with meadows occurring along valley bottoms. Some of this range is heavily grazed by sheep and cattle during summer, and over a longer season by deer and elk. The range lands below the fringes of the forest area have more extensive grassland. They furnish spring and early summer feed for livestock, and winter forage for big game. The lower elevation plains and plateau range land east of the Cascades is characterized by grasses, weeds, and sagebrush. It is used as winter range by domestic stock.

	Cropland & pasture		Crop types					
Area	Irrigated	Non-irrigated	Orchard	Row Crops	Close seeded crops	Sod Crops	Fallow	Other
	acres	acres	acres	acres	acres	acres	acres	acres
Columbia Basin States	4,105,000	14,421,000	323,000	733,000	7,772,000	4,669,000	4,201,000	751,000
British Columbia	150,000	998,000	41,500	41,700	276,800 (187,000 in Arctic drainage)	608,000	180,000	
Southern Alaska	1/	850,000	1/	1,000	18,000	1/	1/	1/

1/ No data available

The figures given above are subject to change as new irrigation developments bring new land into cultivation and as new farming practices and price structures divert effort from one type of crop to another. But they indicate the broad breakdowns satisfactorily for use here.

The great bulk of the range land lies in the Columbia Plateau and Snake River Plain provinces, with considerable areas in the Okanogan Highlands, British Columbia Plateau, Rocky Mountains, and east side Cascade foothills. Big game consumes about twenty per cent of the forage produced on open

range land, and about thirty per cent of that produced on forested range. Big game populations are estimated to include more than 1,600,000 deer, 200,000 elk, 25,000 antelope, 25,000 mountain goats and bighorn sheep, and perhaps 50,000 moose. In British Columbia there are also several thousand caribou.

Developed Lands. In this class are included urban and suburban residential and industrial areas, airports, highways and railroads. Though the total area involved in development is minor, averaging less than one per cent of the total, the ground disturbance and the activities inherent in development create real and significant problems. Homesites in urban and suburban areas and on farmsteads occupy nearly a million acres. Industrial developments push the total well over two million acres. Roads and railroads take up another half to three-quarter million acres. With airports, recreation areas, and other developments, the grand total would equal more than three million acres of developed land which is greatly changed from the original natural conditions. This category is expanding at a rapid rate and the land devoted to these uses will increase many-fold in the foreseeable future.

Barren Land. In this class are included coastal sand dunes, expanses of bare rock, glaciers, and permanent snowfields. In British Columbia and southern Alaska barren land includes slightly less than half the total area, but in the Columbia Basin States only about four per cent of the total. For the whole region, about 109,000,000 acres - nearly a quarter of the total area - are called barren. The principal "crop" of the barren land is water.

LAND OWNERSHIP

Ownership by kind of land is shown in table following:

About three-quarters of the total land area is in public ownership, mainly at the national level. The Federal lands in the United States and the Crown lands in British Columbia include the principal water-producing areas of the Pacific Northwest. The development and management of these public lands is of prime significance to protection of the water resource.

LAND USE, CONDITION, AND MANAGEMENT

Use of land may significantly alter physical conditions. Conversion of forest land to cropland removes the protective cover vegetation and bares the soil to erosion. Cultivation may change soil characteristics to reduce infiltration and increase runoff and erosion. Heavy grazing use on range land may compact the soil and greatly reduce infiltration in addition to removing much of the grass and weed cover. Urban and industrial developments, roads and streets, all present large areas of impervious roof and pavement that speeds up runoff. Harvesting the timber from forest land opens the forest and affects the storage and melt rate of snow. The timber harvesting machinery and development of access may disturb normal soil conditions over significant areas. Any or all of these operations may be reflected in turbidity and sediment and lowered water quality, and in altered seasonal distribution of streamflow. The blockading effect of debris jams following fire, windthrow, or careless logging on slopes above channels may close the channels to fish passage, may increase the hazard of flood surges, and may add nutrients and alter the temperature of the water.

Forest Land. Forest land is used not only for timber production, but also for grazing by domestic stock and game animals, for mining and some forest-based industries and for recreation. Timber harvesting and grazing have had the greatest impact on the land of any planned operations, but wild-fire also has over the years contributed much to change forest land conditions.

COLUMBIA BASIN STATES

Ownership	Forest	Range	Cropland		Other
			irrigated	non-irrigated	
	acres	acres	acres	acres	acres
National gov't.	53,705,000	36,444,000	201,000	546,000	4,552,000
State and local gov't.	4,208,000	3,466,000	8,000	196,000	213,000
Private	26,642,000	24,348,000	3,896,000	13,679,000	2,418,000

BRITISH COLUMBIA

National gov't.	1,089,000	1/			1/
State and local gov't.	128,998,000				
Private	6,595,000		150,000	998,000	

1/ No data

SOUTHERN ALASKA

	(Commercial)				
National gov't.	4,250,000	160,000			1/
State and local gov't.	1/	1/			
Private	19,000			850,000	

1/ No data

Orderly development of mountain watersheds for timber harvest, power lines, and recreation can be accomplished without damage to water resources

Fire is in some forest areas a natural result of a climate that includes dry lightning storms, but may result from man's carelessness in any forest area.

Based on productivity of recently-cut forest land, conditions by ownerships on United States lands are estimated as follows:

Ownership	Forest Land Condition Class 1/ Good	Fair	Poor
	Percent of total area		
Columbia Basin States			
Federal	88	12	0
Local public	70	19	11
Industrial	94	5	1
Small private	58	31	11
Average	81	15	4
Southern Alaska			
Federal	89	11	0

(From Timber Resources for America's Future, FS Report No. 14, 1958)

1/ Defined in terms of stocking, or density of desirable tree species.

Appraisal of condition in terms of the above estimates has several major weaknesses: the estimates do not include cutover areas more than six years old, they do not include burned areas, they do not include about a third of the industrial forest ownerships, there are no data for British Columbia, and as far as watershed conditions are concerned it is only assumed that they are closely correlated with timber-growing conditions. A poorly-stocked timber stand with dense brush growth may provide excellent watershed protection. On the other hand, relatively small areas with poor cover and greatly disturbed soil may cause significant damage to water resources. Many areas of poor watershed are that way as a result of events many years past.

However, the figures do serve to indicate the effects of management (or lack of it) on different ownerships. Some industrial holdings devoted almost solely to wood production and including the best timber-growing sites are in very good condition. Federal holdings long managed for multiple use purposes (but on the average perhaps less intensively managed than the industrial properties) also show up very well. Other public holdings, in smaller blocks and subject to varying degrees of management, rate fairly well but can be significantly improved. The small private holdings show up poorly and reflect a lack of management. In this latter case, the small watershed program of the Department of Agriculture should stimulate some improvement.

Range Land. For the Columbia Basin States, the breakdown of range land condition by cover types is as follows:

Cover Type	Range Land Condition Class 1/ Good	Fair	Poor
	Percent of total area		
Non-forested			
Mountain brush	18	40	42
Sagebrush-desert shrub	13	34	53
Perennial grass & weeds	25	37	38
Meadow	24	38	38
Annual grass & weeds	14	26	60
Average	17	34	49
Forested range	33	38	29
Overall average	22	35	43

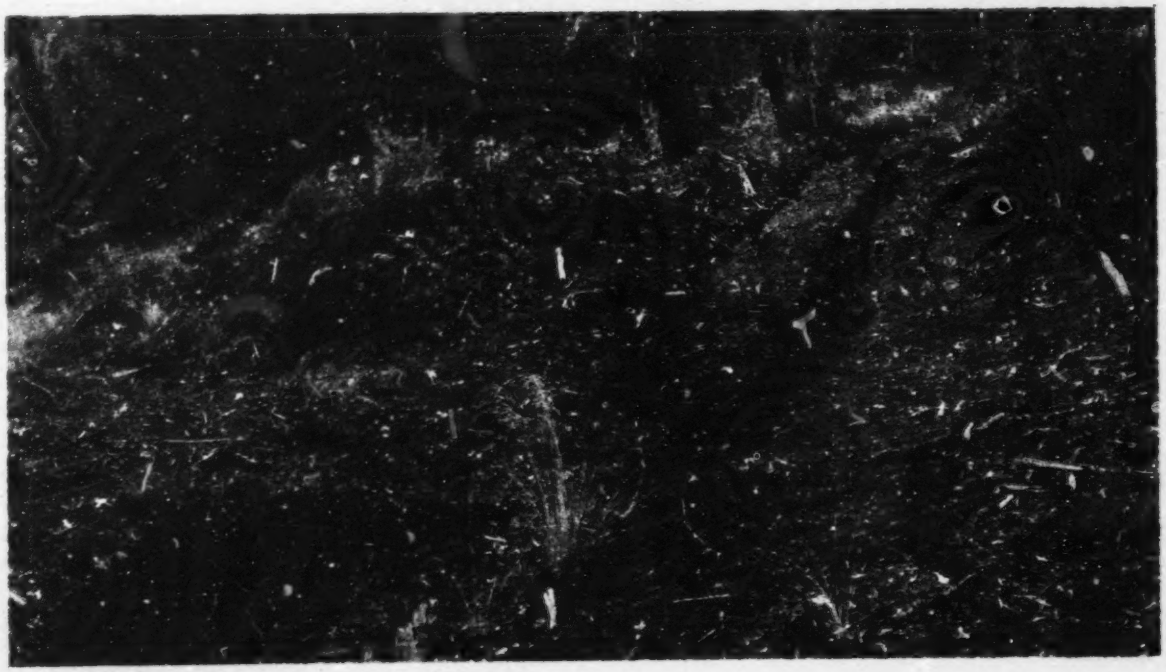
1/ Defined in terms of density and species composition of the cover.

No comprehensive estimates are available on condition of range land in British Columbia.

The forested range is in much better condition than the open range which is and has been much more heavily used. The open range annual grass and weed type is the worst; this is in part because it represents the endpoint of deterioration of perennial and meadow types and occupies in the main the most heavily used areas. Since range condition is estimated both in terms of forage plant density and growth rate, it is fairly closely correlated with watershed condition. However, the standards for good watershed condition may be considerably higher than for good range condition, because adequate forage can still be produced from soils with lowered infiltration capacity.

The non-forested range land must be rated as poor from the watershed standpoint. This rating reflects almost a century of abuse over much of the range area. Though conditions are improving today, the rate of rehabilitation is slow and much remains to be done. The great bulk of the range is in public ownership, and only relatively recently has been given any real management. Management as well as rehabilitation has a long way to go.

Cropland. While not often comprising a large part of upper watershed areas, cropland has its effects on the water resource. From various sources it is estimated that the agricultural soils have lost a third to a half of their original organic matter content since they have been cultivated, that soil texture has generally deteriorated under cultivation, that saline accumulations have degraded nearly a million acres of cropland, that improper irrigation has created a drainage problem and lowered productivity on another million acres, that invasions of noxious weeds have caused abandonment of about a hundred thousand acres, and that soil loss from erosion of improperly cultivated fields is widespread and rapid. All of these factors are significant to the water resource, as cropland erosion sediments and irrigation return flows adversely affect water quality throughout the entire region. Irrigation is the major consumptive use of water, and inefficient distribution and application may waste much of the available water resource. Irrigation return flows carry minerals in solution leached from the soil or from fertilizers applied to the soils, and also carry residues of toxic pesticides and weedicides. The amounts and kinds of materials carried will vary with the soil type and with cultural and irrigation practices.



Uncontrolled drainage in abandoned logging skidtrails often causes serious erosion and adds to stream turbidity and sedimentation

Skidding logs down draws and live stream channels causes excessive stream turbidity and sedimentation

Important Watershed Characteristics

PLANT COVER

The rate of movement of water either across or into a watershed surface is influenced in large part by the amount and kind of cover and soil on the watershed. Plant cover also strongly affects factors in the soil, particularly surface infiltration capacity.

When water is furnished to the watershed in the form of snow, the plant cover may control snow storage and melt rate. It thus can effect - to a small but significant degree - both total water yield and distribution of the yield as streamflow.

The principal value of cover is in shielding soil from the beating action of raindrops, and in maintaining and improving soil infiltration capacity and permeability. The cover itself intercepts some precipitation which is lost again by evaporation. The organic litter beneath the cover has a sponge effect, holding some moisture, and slowing the movement of what it cannot hold. As the litter decays and becomes incorporated with the soil, it improves soil structure, both in porosity and in moisture-holding capacity. Plant roots penetrating the soil body also increase soil porosity and provide additional means of temporary storage and transmission of moisture within the soil. The presence of plant and litter cover greatly reduces the effects of frost which may make soil temporarily impermeable. Plant roots bind the soil, increasing its stability against movement by gravity or wind or water.

Though plant cover takes its toll of the water resource to make its own growth, it repays this tax in the protective services given the watershed. Where there is no cover, there is too much water at some seasons and not enough at others. Floods alternate with drought, and the water made available is often too turbid and sediment-laden for use. Plant cover is a water regulator and cleanser.

SOIL

Several physical characteristics of the soil affect water production and are of interest to watershed management. Soil depth controls in large measure the amount of water that can be temporarily stored on a watershed and slowly released to maintain streamflow. Notable exceptions occur in soil-less lava beds and talus slopes where deeply fissured rock and the spaces between rock fragments provide temporary water storage and flow regulation, as at the head of the McKenzie River in Oregon. Generally, however, the greater the soil depth the greater the storage space available and the better the regulation of water movement to streams.

Texture and composition of the soil also strongly affect its porosity, infiltration capacity and moisture storage space. Sandy soils of single-grain structure and composed of particles of more or less uniform size will have a high acceptance (or infiltration capacity) for water but will permit fairly rapid percolation to streams and will hold only small amounts of water against gravity. Loam soils of crumb structure will have a high infiltration capacity as long as the soil surface is protected by plant cover or organic litter against possible puddling and sealing. Such soils will permit moderate percolation over a fairly long period and will retain relatively large amounts of water. Clay soils will take in water less readily, are often easily puddled, will permit only slow percolation, and will permanently retain moderate amounts of water.

Temporary detention storage space in the larger soil openings that drain by gravity ranges from 40 per cent in sand soils to 20 per cent in loams and 5 per cent in clays. Percolation rates range from 140 inches per hour in sands to 0.5 inches per hour in clays. Retention storage in small capillary openings that hold water against gravity ranges from 15 per cent for sandy soils to 40 per cent for loams and 60 per cent for clays. These figures are general.

Infiltration rates have not been determined for forest soils within the region but probably range from 3 to 6 inches per hour for sandy soils, 1 to 4 inches per hour for loams, and 1/8 to 1/2 inch per hour for clays, as indicated by studies elsewhere. Infiltration rates may vary according to the type and density of cover vegetation, being affected by interception, canopy effect and root extension.

Amounts of organic matter incorporated into the soil affect the porosity, percolation rate and storage space. Organic litter accumulations on the soil surface prevent puddling and sealing and maintain high infiltration rates. Both on the surface and incorporated into the soil body, organic matter protects against erosion. Because of its contributions to soil structures and the protection it affords to the soil surface, organic matter is important to watershed management.

Stability of the soil may be defined as its tendency to remain in place and keep its structure despite the action of such factors as gravity, percolating water, the weight of the forest cover, denudation by fire or grazing, and disturbance and compaction by logging equipment. Stability depends on soil composition and structure, topography and amount of soil moisture. Loam soils usually consist of aggregates of a wide size range of soil particles and are usually high in organic matter content and quite stable over a wide range of conditions. Single-grain structure soils are less stable than loam soils. Sands and silts may be fairly stable when moist and very unstable when dry, but with clay the opposite may be the case. With too much moisture, either sand or clay may be lubricated enough to flow. On a sufficiently steep slope, any soil may be unstable.

Erodibility is to some extent the reverse of stability. However, an unstable soil in a protected position might not be considered erodible while a usually stable soil in an unprotected position might be highly erodible. Sands and silts laid bare are subject to movement by wind and water. Clays provided with excess moisture to lubricate the substrata might be moved by their own weight or by pressure from the weight of the forest they support. Soil erodibility might restrict operations in the forest on areas of unstable soil because objectives of watershed management include keeping soil from becoming stream-borne sediment.

Soil deterioration includes puddling and sealing of the soil surface, compaction and loss of porosity, change from an aggregate to single-grain structure, and decreased stability and increased erodibility. There are many causes of soil deterioration, the most rapid-acting of them associated with use and operations on the land. The changes they bring about are of immediate concern to watershed management.

Where the soil surface is puddled and sealed by the beating action of rain, water runs off rapidly to the streams and erodes away the upper layers of soil as it goes. Streamflow builds up sharply to high peaks bulked further by erosion sediments. As the sediments settle out, they also provide a seal. Infiltration rates are greatly reduced, and little water finds its way into the soil.

As topsoil is removed and soil depth is decreased by accelerated erosion, the soil is less able to support a plant cover. There is less moisture-storage space and less control of runoff and streamflow. The chain reaction of erosion may proceed until the soil is eaten away to bedrock. Then nearly all surface water immediately becomes runoff; streams rise in flash floods and soon drop to expose sediment-choked channels. The streams are dirty and turbid as long as they flow, the water is unfit for many uses, and the seasonal yield distribution is upset.

What is described above is an extreme case, a case occasionally attributable to man's activities. Such extremes have occurred in only limited areas within the region. The effects of deteriorated conditions on streamflow are, however, far out of proportion to the size of the areas involved. Causes of deterioration are highly significant and must be avoided or removed by proper management.

Soil deterioration and accompanying watershed ills can be prevented. What has happened in the past has happened from ignorance and carelessness. It need not continue. On most watersheds and over a wide range of soil and climatic conditions, operations of various kinds can be controlled or modified to avoid watershed damage. In the following pages adverse effects of various factors are cited. This is done to bring attention to matters that need consideration and does not mean that such effects are inevitable.

Forest fires increase erosion and sedimentation as well as providing soluble ash to contaminate streamflow

Water Uses Affected by Watershed Activities

Various watershed activities can and do cause damage to domestic, industrial and agricultural water supplies; to swimming and other recreation; to the growth and propagation of fish, shellfish, and other aquatic life. Physical, chemical and bacterial changes in the quality of water resulting from the lack of adequate watershed control measures and management practices cause economic losses to each of these water uses and reduction of the value and usefulness of the water resources to society.

DOMESTIC AND INDUSTRIAL WATER SUPPLY

Surface water supplies are used by more than 400 communities in supplying domestic needs for more than 6,000,000 people living in the Pacific Northwest (including British Columbia and Alaska). A large number of industries obtain their water for process operations and cooling purposes from the municipal systems. However, a considerable number of the larger industries obtain their water supplies directly from surface sources. The average daily surface water requirement for domestic and industrial use in the Pacific Northwest exceeds 3 billion gallons. This demand will grow as population grows.

The important physical changes usually occurring in surface water supplies obtained from watersheds where the control measures and management practices are not adequate are in turbidity, color, temperature, settleable solids, taste and odor. These effects can be alleviated by a number of treatment methods such as chemical treatment, aeration, coagulation, sedimentation and filtration, but the end product, although acceptable, is frequently less desirable than naturally pure water. If all municipalities and those industries requiring clear water were faced with the problem of removing turbidity, color, taste, and odor from their water supplies, it is estimated that the additional cost of treatment in the Pacific Northwest would be measured in millions of dollars annually.

Some of the substances which affect the quality of surface water supplies and which land use and management practices may allow to reach streams are lead, arsenic, copper, iron, magnesium and zinc ions, calcium sulfates, chlorides, phenolic compounds, oil, gasoline, acids, alkalies, cyanides and insecticides. Even limited amounts of some of these substances in a water supply used for domestic and some industrial purposes are dangerous to health, to fisheries, and limit industrial use of that supply. Nutrients and radioactive materials also present problems. Treatment of all surface supplies in the Pacific Northwest to remove various amounts of these chemicals and make the water usable for domestic and industrial processing purposes would cost several million dollars annually. Such substances as chloride, phenolic compounds, oil, gasoline, acids and insecticides are difficult to detect and costly to remove from water.

Water obtained from surface sources in Pacific Northwest watersheds unaffected by activities of man is usually of excellent quality and can be used for domestic and most industrial purposes with limited treatment. Uncontrolled watershed activities may result in both turbidity and in bacterial contamination of the water supply and require much more extensive treatment. Costs of treatment by simple disinfection are quite cheap. More extensive treatment to include filtration and disinfection of polluted waters may increase the cost from 20 to 40 times.

AGRICULTURAL WATER SUPPLY

Surface waters are used to irrigate more than 5,000,000 acres of land in the Pacific Northwest. In addition, in many localities they are the only available source of water supply for farm domestic use, stock-watering and other agricultural uses.

The quality of water required for irrigation, stock-watering and agricultural uses other than for domestic purposes is not affected as greatly by watershed practices as are some of the other principal uses. However, water polluted by drainage from mines and the discharge of tailings from flotation mills may contain chemicals and minerals detrimental to the growth of some crops and unsafe or unacceptable for drinking by livestock. Excessive amounts of silt, algal growths, slimes and debris may clog ditches, pipes and spray nozzles, reduce the capacity of storage reservoirs, and interfere with the operation of entrance gates to canals and pumping stations, thus increasing the cost of operation and maintenance of irrigation projects.

Clear sparkling water from an undisturbed mountain watershed

Clean-up of reservoir flowage areas is necessary to preserve scenic beauty and to reduce recreation hazards

A lucky steelhead fisherman on the Sandy River, Oregon

Water is obtained from canals and stored in cisterns for domestic use by many farm families living in irrigation districts where ground water supplies are not available. This water, often used without disinfection and treatment, is not considered by Public Health officials to be a safe supply.

SWIMMING AND OTHER RECREATION

Polluted water destroys many recreational opportunities. Swimming in such waters is not recommended and sometimes may be prohibited by health authorities. Contaminated water requires treatment before use in swimming pools.

Water containing excessive amounts of silt, floating logs a branches, and other solids and bacterial contamination is neither safe nor suitable for fishing, boating, water skiing and other recreational uses. Polluted waters unpleasant to the eye and to the nose decrease the value of riparian property and destroy social values in communities through which they flow.

GROWTH AND PROPAGATION OF FISH, SHELLFISH AND OTHER AQUATIC LIFE

Desirable fresh water fish common to the Pacific Northwest require clean water. In the Pacific Northwest there is little fishing for such species as can survive in silt-laden waters.

In addition to clean water, most species of fish common to the Pacific Northwest require clean gravel in which to spawn and hatch their young. Good gravel spawning areas in a clean stream have a very high value per acre in terms of fish production. Many of the organisms and other aquatic life on which fingerlings and other fish feed survive only in clean water. As an example of the direct economic loss to fish, the Hells Gate slide on the Fraser River during railroad construction in 1913 is estimated to have cost one billion dollars in fish production due to stoppage of migratory fish runs.

Fish that migrate from salt water and from fresh water lakes upstream to spawn can travel through turbid water. However, their progress can be impeded or entirely stopped in waters of substandard quality because of oxygen deficiencies, the presence of petroleum products or other chemicals, or blockading log jams and other debris. Fish kills have occurred from accidental and other discharge of toxic substances into surface streams.

In waters where shellfish are grown for public consumption, very strict requirements exist in regard to bacterial contamination. In addition, silt deposits from streams flowing into the tidal estuaries where shellfish are grown reduce productivity.

PRINCIPAL CHANGES IN WATER CAUSED BY WATERSHED ACTIVITIES

The principal physical, chemical and bacterial changes in water which are most likely to be caused by various watershed activities are noted in the following tabulation:

Changes in Quality of Water	Construction Activities	Agriculture	Timber Harvesting & Mgt	Grazing	Mining	Recreation
Bacterial contamination	X	X	X	X	X	X
Turbidity	X	X	X	X	X	X
Taste & Odor	X	X	X	X	X	X
Color	-	-	X	-	X	-
Mineral Solutes	X	X	-	-	X	-
Acidity	-	-	-	-	X	-
Toxic Chemicals	-	X	X	-	X	-
Oil Scum	X	-	X	-	-	X
Gasoline Scum	X	-	X	-	-	X
Objectionable Solids	X	-	X	-	-	X
Temperature	X	X	X	-	X	-
Erosion Sediments	X	X	X	X	-	-
Nutrients	-	X	-	-	-	-

Any one watershed activity possibly could cause all of the changes in the quality of water listed in the preceding table. However, only the most common effects are checkmarked for each of the watershed activities.

Water quality and the aquatic habitat in Western Oregon are not served by this kind of road maintenance

Hillside location of forest access roads, necessitated by reservoir construction, creates tremendous disturbance of the soil

Sources and Causes of Pollution on Watersheds

SEDIMENT AND TURBIDITY

Erosion of Disturbed Soil

Erosion is a natural process. When it occurs at low natural rates on undisturbed soil it is not often harmful. However, it can at times be catastrophic, as in landslides. On the other hand, accelerated erosion, which usually follows uncontrolled use or unwise development of the land, is a major source of damage to water supplies on the producing watersheds. Much of the Pacific Northwest - and most of its productive watershed area - is forested. Forest use and development is therefore highly significant to protection and development of the water resource.

Various activities on forest lands contribute to soil disturbance. Road construction is perhaps the most important but logging operations and fire may also have serious effects. On range lands, too heavy grazing use which removes the plant cover and compacts the soil leads to accelerated erosion. On agricultural lands, improper cultivation methods are the principal factor in rapid runoff and high rates of soil loss, leading to plugged channels, meandering and bankcutting, and increased flood overflow as well as damages to water quality.

Construction of roads, railroads, dams, power transmission lines, and pipelines may disturb the soil over as much as eight per cent of a given drainage area and add huge quan-

Logging debris left in streams and overcast material from roads needlessly increases flood damage and sedimentation

tities of displaced soil and erosion debris to the streams. Silt is frequently washed into streams from overcasts of excess rock and soil, from cut and fill slopes, from borrow pits, and from aggregate washing and handling facilities. Excavations for bridge abutments and foundations for dam and tower structures are another source. Improper use and maintenance of roads may increase silt and turbidity problems; the wheels of vehicles traveling rutted, poorly surfaced roads splash mud into watercourses and careless maintenance work may undercut side slopes and increase soil movement in roadside ditches that drain to streams. Though the effect of passage of a single vehicle is small, the aggregate effect of many vehicles over a period of time is quite significant.

Entirely aside from the numerous access roads in timber-producing areas, the timber harvesting operations themselves may disturb the soil over more than twenty per cent of the operating area and create severe erosion hazards. Logging operations are a prime cause of temporary decline in water quality. Until the forest vegetation is removed, most watersheds produce fairly clean water; it is in virgin forest areas that a great number of the public water supplies of the Pacific Northwest have their source. Unless the utmost care is taken in planning and carrying on logging operations, declines in water quality will extend upstream as timber harvest moves into headwater areas. Silt frequently washes into streams from poorly located and improperly built temporary spur roads and tractor skidtrails, or from the dragging of logs directly downslope and across stream channels in cable logging.

As a case in point, we might consider the Green River in western Washington. This stream, part of the water supply for the city of Tacoma, has a long narrow watershed extending from Stampede Pass at the crest of the Cascades to Puget Sound. The headwaters are steep forested mountain slopes between elevations of 2000 and 5000 feet. Rainfall is fairly high and a large flow of water is assured. But a transcontinental railroad runs the length of the watershed, crossing the stream several times. Extensive logging operations are going on in the watershed and there is a considerable mileage of

timber access road. Other use is not heavy, but there are some private homes and some summer recreation use in the area, with attendant fire hazards. A large flood-control dam is now being built in the lower part of the watershed, with attendant relocation of the railroad. Soil disturbance is great and turbidity often a problem. Because of the relatively high human use and occupancy, bacterial contamination is a constant threat. There is no mining in the watershed, there is little big game and no livestock grazing, and agriculture exists only in the flat valley below the city's water intake. While some control of entry and use is exercised by the city, maintenance of water quality depends largely on cooperation by the landowners in management of road construction and timber harvest operations, cooperation by watershed occupants in disposal of refuse and sewage, and on cooperation by the railroad in the matter of disposal of human wastes on trains passing through. Minimizing soil disturbance to prevent erosion and to keep turbidity and sediment out of the stream, and intensive protection against fire are major problems.

Fire is a constant threat on forest and range lands. Wildfire - whether natural, accidental or willfully set - may remove both the living plant cover and much of the organic litter on the ground surface from large areas. Slash disposal fires on cutover forest and burning for weed and brush removal on ranges, unless carefully managed in terms of weather and fuel moisture, may have the same effect. The soil laid bare to wind and rain erodes rapidly; freshly burned slopes have produced many thousands of cubic yards of sediment per square mile of area denuded. Abnormal erosion continues until plant cover is re-established, which may require several years. Ash and charred debris are also carried into streams to the detriment of water quality.

On many watershed range lands, past grazing use has been excessive; denuded ranges contribute disproportionately large amounts of runoff to flash floods and erosion sediments to channels downstream. Grazing use is less intensive and is better managed now, but the effects of past misuse are still evident. Natural rehabilitation of soil and cover is a very slow process and may not alone be able to stop the cycle of degradation. Pasturing stock in meadows may increase stream turbidity and sediment loads where stock cross streams or trampling by stock breaks down stream banks and constantly roils the water. The soil of areas for stock feeding and watering may become greatly disturbed by concentrations of animals and also contribute significantly to stream turbidity and sediment.

Several agricultural activities involve varying degrees of soil disturbance. Cultivation may lay the soil completely bare of cover over large areas and leave it unprotected against movement by wind and water. Net movement is downhill, into watercourses. Silt which reaches streams from eroding farm lands is a major cause of high turbidities in waters of the Pacific Northwest. Cultivation other than on contour is particularly hazardous in that it provides new channels for rapid runoff and erosion. Erosion losses connected with irrigation, caused by improper application and removal of water, may be as great as 20 tons of soil per acre per year. In the dry-farmed Palouse region of eastern Washington with fine, silty soils, erosion in one storm - where warm rain fell on deeply frozen ground - reached 300 tons per acre. On two million acres of the Palouse area the average erosion loss is 13 tons per acre per year, and on eight million acres more the average loss is three tons per acre per year. 1/ This erosion loss amounts to 30,000 acre-feet of soil annually. About 25 per cent of the erosion sediments measured in small watersheds are carried down to the major streams.

1/ Report on Agricultural Program, Big Bend-Palouse-Lower Snake Sub-Area, U.S. Dep't. Agriculture, May 1954.

Mining and Milling Wastes

Mining activities may also contribute to stream turbidity and sedimentation, though effects are usually local. Mine dumps may erode directly into streams and mine access roads and trails may constitute further sources of erosion sediments. Unless properly lagooned, effluents from milling operations may impair water quality. Dredge and hydraulic operations are particularly disturbing to streams and soil and have been a prime sediment source in some drainages.

Landslides and Avalanches

Certain natural phenomena of catastrophic geologic erosion regularly contribute to stream sediments and turbidity. Landslides caused by earthquakes or from unstable soil and rock formations heavily lubricated by ground water in abnormally wet seasons or undermined by stream bankcutting may discharge huge quantities of soil and rock and organic debris into streams all at once. Snow avalanches in the higher mountains every winter bring down large amounts of plant material, soil, and rock to stream channels; however, since avalanches tend to repeat at irregular intervals in the same channels which are already scoured fairly clean, most of the debris is plant material. Frequency and size of landslides and avalanches may be drastically increased by activities on the land. Uncontrolled fire has increased avalanche hazards in many mountain areas.

Bankcutting

Undermining and caving of stream channel banks is a form of erosion that everywhere contributes significantly to stream sediment loads and turbidity. In mountain areas the slow creep of the soil mantle, pulled incessantly downslope by gravity, continually presents material to be cut away at times of high streamflow. Changes in streamflow regimes brought about by changes in upstream watershed conditions may increase bankcutting. In lower areas where the streams have flatter gradients, sediments are dropped in the channel beds and the streams seek new courses, cutting into existing banks in the process.

Bankcutting along the Touchet River in southeastern Washington, for example, causes an average loss of 15 acres per year and sediment loads have been measured up to 82,000 parts per million, or 8.2 per cent by volume. Streambank erosion caused the loss of more than 60 acres of cropland and pasture in the John Day River valley in the 1951 and 1952 runoff seasons. In the Willamette River valley bankcutting losses amounted to several million cubic yards in the 1943 flood alone; average annual land losses are estimated at $120,000 equivalent value.

CHEMICAL POLLUTION

Agriculture

Numerous chemicals used in fertilizer and pest control sprays and dusts, or leached from saline soil, or dissolved in drainage from farmsteads and feed lots may adversely affect water quality. Crop wastes left in the field are another source of pollution. Return flows from irrigation are perhaps the most widespread source, carrying salts leached from the soil and fertilizers, or pest poisons applied too liberally or carelessly. Irrigation is often used specifically (under controlled conditions) to remove excess salts from the soil. Organic solutes from livestock feed lots, corrals, manure storage, and barns may be carried both by overland runoff and ground water drainage. These chemicals may be toxic, but in other instances may add nutrients that cause undesirable slime growths in the receiving waters or create an oxygen deficiency. Household chemicals may be added to ground water by drainage from farmstead sewage disposal systems. Gasoline, oil, clean-

sers, paint, or other chemical spills around farmsteads or wherever machinery is used may also add to the pollution load.

Forest and Range

Several sources of chemical pollution of water exist on forest and range lands. The most prevalent are the tannin and humic acid complex solutes leached from decomposing natural organic litter and from logging slash accumulations in watercourses. Hemlock trees have high tannin content in leaves and bark; hemlock slash in water soon leaches enough to discolor streamflow. Other timber species have similar effects. Leaves shed by the deciduous alders, willows, and cottonwoods that usually grow in wet sites seasonally increase the pollution load.

After fires, ashes blown or washed from the burned areas may add significantly to the dissolved load of streams and reduce the quality and usefulness of the water. Major effects usually are noticed only in the first wet season following the burn, but where there has been a hard burn and a sharp change in soil chemistry, changes in chemical quality of streams draining the area may endure two to three seasons. The pH is usually raised; water that is normally neutral or slightly acid may become slightly alkaline. Potassium and phosphorous ions show greatly increased availability in burned forest soils, and it is reasonable to expect similar increases in the water draining such soils. Nitrates tend to be destroyed by burning; at most, only a very temporary increase of nitrate in streamflow could be expected from a burn.

On logging jobs, in road construction, on range reseeding, or any other job where power machinery is used, there may be a certain amount of pollution from oil and gasoline spills and leakage. As the timber harvest gradually extends over a watershed this hazard increases. Drainage from heavily used recreation areas may provide similar hazards. Motor boats on lakes and streams also increase the amount of oil and gasoline pollution.

Chemical sprays are used for various purposes over wide areas of forest and range. They may consist of insecticides or fungicides, weed killers or fire retardants. Some are highly toxic. Where over-applied or carelessly and unwisely applied near stream courses, they may provide a serious pollution threat.

Industry and Utilities

Industrial activities on watersheds away from urban centers may have serious impacts on water quality. These activities include primarily mining and lumber milling. Mine drainage and leaching of mine dumps may contribute mineral solutes in fairly heavy and continuous concentrations to streamflow. Minerals deposited from smelter smoke have been known to render water toxic and unfit for general use.

Sawdust piles and storage of logs in ponds afford opportunity for tannins and resins and wood sugars to leach out, as well as providing bark slivers and floating debris. Such drainage into watercourses carries a heavy load of organic solutes to pollute water and make it unfit for many uses. Release of wastes by direct discharge into streams is practiced by many industries. Fruit and vegetable packing and processing operations and pulp milling in some areas provide sources of contamination and pollution. As noted earlier, however, these industrial impacts are not the concern of this manual.

Chemicals in dusts and sprays applied to bind road surfaces may be leached away and carried by road drainage ditches directly to streams. Other chemicals used for weed and brush control along roads may be similarly removed. Oil, gas, and grease drips and spills on roads, or anywhere that machinery is operated, add another source of pollution.

Leaks in pipelines used to transport gas and oil and other products, or storage facilities for these products, may also be significant local sources of pollution.

Smoke from some industries and dusts from others add considerable quantities of chemical pollution to streamflow in many localities.

Construction of major concrete structures such as dams or highways may temporarily add chemical solutes by drainage from fresh concrete surfaces or from chemicals used in curing processes.

PHYSICAL CHANGES

Apart from turbidity and sedimentation which affect light penetration, physical changes in water are limited to temperature from the standpoint of water quality and usefulness for various purposes. Color, odor, and taste are usually assumed to be related to chemical pollutants carried in solution. Temperature affects stream ecology and fish habitat, oxygen carrying capacity of the water, and industrial use of the water.

Agriculture

Return flows from irrigation are usually several degrees warmer than the source from which the water is drawn. This may adversely affect the water as fish habitat, or for industrial use. Clearing land, where it involves removal of brush and trees that shade watercourses, also contributes to increasing water temperature.

Forest and Range

Logging also may remove shade timber along streams and permit stream temperatures to rise a few degrees. On range areas, feeding by beavers and trampling and browsing by big game and livestock may remove streamside shrubs and open the streams to full sunlight with similar effects. Ponding of water by beavers or in stock-watering places also facilitates temperature increases. Depending on local conditions, this warming may or may not be harmful.

Construction

Large reservoirs and diversion ditches and canals permit water to warm considerably. Where streamflow is replenished from reservoir surface waters the outflow may be several degrees warmer than the inflow. Conversely, where the outflow is released from the bottom, it may be cooler, though its oxygen content may also be changed.

Industry

High temperature liquid wastes and cooling waters are sometimes discharged from mines and settling basins, and from various industrial plants. Ponding, whether for supply of water as in sawmill log ponds or for holding liquid wastes, may permit considerable warming before release to streamflow. Severity of these thermal influences depends on seasonal temperature variations and volume of flow in the local watercourses.

BACTERIAL CONTAMINATION

Agricultural Sources

Barns, feed lots, corrals and manure storage sites where livestock wastes are concentrated are all possible sources of pollution of both streamflow and ground water. Farmstead sewage disposal systems are hazardous in areas of high water tables, or where effluents may drain rapidly to underground channels, or in any location if they are not properly designed. Dead animals provide another contamination hazard if carcasses are not promptly disposed of.

Forest and Range

Sewage disposal at administrative sites, work camps, summer homes, and recreation developments provide pollution hazards if not properly planned or if under-designed for the amount of use received. Recreation use, hunting and fishing, whether with or without developments present, greatly increase the hazard from human waste. Swimming and boating in lakes and streams put people in contact with water, increasing both the pollution hazard and the possibility of infection from polluted water. Garbage disposal, or lack of it, around recreation areas and work camps may contribute to bacterial contamination of surface waters. Litter and garbage thrown from cars may accumulate in roadside ditches and increase the pollution load.

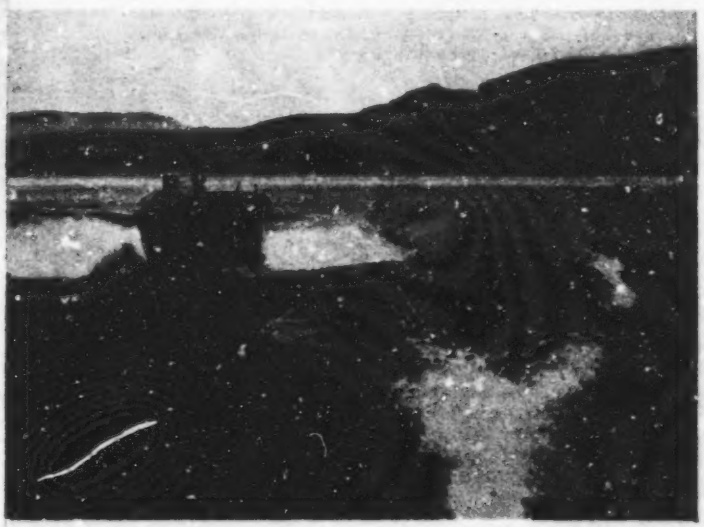
Special problems occur in snow areas where sanitation and disposal of human waste is difficult. These problems are particularly evident in heavily used winter sports areas, or where hunting pressure is great. As the snow melts, the winter's accumulation of wastes may rapidly flush down into streams.

Both livestock and big game animals feeding in and near watercourses add to pollution hazards. Big game must be harvested; if populations grow too large, overgrazing and accelerated erosion will result. Even the carcasses of starved animals dying in streams may be found. Beaver ponds and bearwallows may be sources of high coliform bacteria counts in water supplies. Dead animals and offal from cleaning game in or near watercourses are other sources. In years of epidemic insect infestations, particularly by tent caterpillars which live on hardwood trees and shrubs along watercourses, vast numbers of both larvae and adult insects may fall into the streams and in decomposing present a locally serious pollution problem.

Utilities and Industries

Wastes discharged from railroad trains crossing watersheds are a common source of contamination. The hazard is particularly serious in cold weather when frozen wastes may accumulate in the snow along the tracks and later be flushed into streams.

Construction camps and work camps are possible pollution sources also.



Water Quality Objectives

The Pacific Northwest is at present in an enviable position as regards its natural resources and potential development when compared with many other areas of this country. This is especially true of natural waters which are admittedly one of the area's greatest assets. Water is so definitely tied in with the health, welfare, and pleasure of citizens, and with the whole economic structure of the area as to make high water quality objectives not only desirable, but imperative.

It is hereby declared to be the policy of the Pollution Control Council of the Pacific Northwest Basins to encourage and promote programs for the preservation of the surface and ground waters of the basins and the restoration of such waters to the best possible condition consistent with the public health and welfare, the propagation and protection of fish and wildlife, and the domestic, recreational, agricultural and industrial development of the area.

Whereas it is recognized that many waters of the basins have not yet been adversely affected by industrial, agricultural, or domestic development and, therefore, are of the highest possible quality, one objective of any water conservation program should be to preserve these waters in the best condition consistent with reasonable and beneficial future development.

Whereas it is also recognized that other waters in the basin now exist at a level of quality below that which is necessary and desirable for the best interest of the people, a second objective should be to restore these waters to conditions permitting increased beneficial uses by the people of the area.

With these considerations before it, the Council recommends the following objectives of water quality.

Conditions Applying to Objectives

For waters having more than one use, that use having the highest order shall apply.

In any case where a tributary water which receives sewage or industrial waste flows into waters having a different use than the tributary, and where these tributary waters affect these uses, the objectives with the highest order will apply.

Natural waters may on occasion have characteristics outside of the limits established by the objectives. The objectives set forth relate to the condition of waters as affected by the discharge of sewage, industrial wastes, or other wastes.

There is a blank in the table in the column "Organisms of the Coliform Group" opposite item E, "Agricultural and Industrial Water Supply". A similar water quality objective as for item C, "Bathing, Swimming, and Recreation" should apply wherever human contact is involved. It is desirable to have a safe clean water for irrigation, and uncontaminated water for sawmill log ponds and log debarking operations in order to protect log handlers.

In the column "Taste or Odor-Producing Substances", opposite item B, "Water Supply, etc.", there is reference to a "threshold odor number above eight (8)". This refers to a relative standard for perceptible odor in a water sample, determined by making dilutions of the sample, as explained in "Standard Methods for Examination of Water and Wastewater", American Public Health Association, Eleventh Edition, 1960.

WATER QUALITY OBJECTIVES AND MINIMUM TREATMENT REQUIREMENTS

WATER QUALITY → / WATER USES ↓	WATER QUALITY OBJECTIVES, APPLICABLE TO RECEIVING WATERS, FOR SALT AND FRESH SURFACE WATERS AND UNDERGROUND WATERS									MINIMUM TREATMENT REQUIREMENTS FOR DOMESTIC SEWAGE
	ORGANISMS OF THE COLIFORM GROUP	FLOATING, SUSPENDED & SETTLEABLE SOLIDS & SLUDGE DEPOSITS	TASTE-OR ODOR-PRODUCING SUBSTANCES	DISSOLVED OXYGEN	pH	TOXIC, COLORED, OR OTHER DELETERIOUS SUBSTANCES	PHENOLIC COMPOUNDS	OIL	HIGH TEMPERATURE WASTES	
A WATER SUPPLY, DRINKING, CULINARY & FOOD PROCESSING WITHOUT TREATMENT OTHER THAN SIMPLE DISINFECTION AND REMOVAL OF NATURALLY PRESENT IMPURITIES	MOST PROBABLE NUMBER COLIFORM BACTERIAL CONTENT OF A REPRESENTATIVE NUMBER OF SAMPLES SHOULD AVERAGE LESS THAN 50 PER 100 ML. IN ANY MONTH	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES OR OTHER WASTES OR WHICH, AFTER REASONABLE DILUTION & MIXTURE WITH RECEIVING WATERS, INTERFERE WITH THE BEST USE OF THESE WATERS FOR THE PURPOSE INDICATED	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES	GREATER THAN FIVE (5) PARTS PER MILLION EXCEPT FOR UNDERGROUND WATERS	HYDROGEN ION CONCENTRATION EXPRESSED AS pH SHOULD BE MAINTAINED BETWEEN 6.5 & 8.5	NONE ALONE OR IN COMBINATION WITH OTHER SUBSTANCES OR WASTES IN SUFFICIENT AMOUNTS OR OF SUCH NATURE AS TO MAKE RECEIVING WATER UNSAFE OR UNSUITABLE FOR USE INDICATED (U.S.P.H.S. STDS.)	LESS THAN FIVE (5) PARTS PER MILLION	NONE	NOT IN SUFFICIENT QUANTITIES ALONE OR IN COMBINATION WITH OTHER WASTES TO INTERFERE WITH THE USE INDICATED	SEDIMENTATION AND EFFECTIVE DISINFECTION
B WATER SUPPLY, DRINKING, CULINARY & FOOD PROCESSING WITH TREATMENT EQUAL TO COAGULATION, SEDIMENTATION, FILTRATION, DISINFECTION AND ANY ADDITIONAL TREATMENT NECESSARY FOR REMOVING NATURALLY PRESENT IMPURITIES	M.P.N. COLIFORM BACTERIAL CONTENT WHEN ASSOCIATED WITH DOMESTIC SEWAGE OF A REPRESENTATIVE NUMBER OF SAMPLES SHOULD AVERAGE LESS THAN 2000 PER 100 ML. AND SHOULD NOT EXCEED THIS NUMBER IN MORE THAN 20 PER CENT OF SAMPLES EXAMINED IN ANY MONTH	SAME AS FOR USE "A" ABOVE	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH, AFTER REASONABLE DILUTION & MIXTURE, WILL PRODUCE THE THRESHOLD ODOR NUMBER ABOVE EIGHT (8)	GREATER THAN FIVE (5) PARTS PER MILLION EXCEPT FOR UNDERGROUND WATERS	SAME AS FOR USE "A" ABOVE	SAME AS FOR USE "A" ABOVE	LESS THAN FIVE (5) PARTS PER MILLION	NONE ALONE OR IN COMBINATION WITH OTHER SUBSTANCES OR WASTES AS TO MAKE RECEIVING WATER UNFIT OR UNSAFE FOR THE USE INDICATED	SAME AS FOR USE "A" ABOVE	SEDIMENTATION AND EFFECTIVE DISINFECTION
C. BATHING, SWIMMING AND RECREATION NOTE: WHEN WATERS ARE USED FOR RECREATIONAL PURPOSES SUCH AS FISHING & BOATING, EXCLUSIVE OF BATHING & SKINDIVING, THE NUMBER "2400" MAY BE SUBSTITUTED FOR "240" IN STATEMENT OF COLIFORM OBJECTIVE	COLIFORM BACTERIAL CONTENT OF A REPRESENTATIVE NUMBER OF SAMPLES SHOULD AVERAGE LESS THAN 240 PER 100 ML. AND SHOULD NOT EXCEED THIS NUMBER IN MORE THAN 20 PER CENT OF SAMPLES EXAMINED WITH ASSOCIATED WITH DOMESTIC SEWAGE (SEE NOTE UNDER "C" AT LEFT)	SAME AS FOR USE "A" ABOVE	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH, AFTER REASONABLE DILUTION & MIXTURE, WILL INTERFERE WITH THE BEST USE OF THESE WATERS FOR THE PURPOSE INDICATED	GREATER THAN FIVE (5) PARTS PER MILLION	SAME AS FOR USE "A" ABOVE	SAME AS FOR USE "A" ABOVE	LESS THAN 25 PARTS PER BILLION OR NONE IN SUFFICIENT AMOUNTS SUCH AS TO IMPART A RESIDUAL TASTE TO RECREATIONAL OR COMMERCIAL FISH, SHELLFISH, OR OTHER AQUATIC FORMS	SAME AS FOR USE "B" ABOVE	SAME AS FOR USE "A" ABOVE	SEDIMENTATION AND EFFECTIVE DISINFECTION
D GROWTH & PROPAGATION OF FISH, SHELLFISH & OTHER AQUATIC LIFE	COLIFORM BACTERIAL CONTENT OF A REPRESENTATIVE NUMBER OF SAMPLES SHOULD NOT HAVE A MEDIAN CONCENTRATION GREATER THAN 70 PER 100 ML. IN WATERS USED FOR THE GROWTH & PROPAGATION OF SHELLFISH	SAME AS FOR USE "A" ABOVE	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH WILL INTERFERE WITH THE MARKETABILITY OR PROPAGATION OF RECREATIONAL OR COMMERCIAL FISH, SHELLFISH, OR OTHER EDIBLE AQUATIC FORMS	GREATER THAN SIX (6) PARTS PER MILLION	SAME AS FOR USE "A" ABOVE	NONE ALONE OR IN COMBINATION WITH OTHER SUBSTANCES OR WASTES TO SUFFICIENT AMOUNT OR OF SUCH CHARACTER AS TO MAKE RECEIVING WATERS UNSAFE OR UNSUITABLE FOR USE INDICATED	SAME AS FOR USE "C" ABOVE	SAME AS FOR USE "B" ABOVE	NONE IN SUFFICIENT QUANTITY AS TO BE INJURIOUS TO OR INTERFERE WITH THE NORMAL PROPAGATION OF FISH, SHELLFISH, OR OTHER AQUATIC LIFE	SEDIMENTATION FOR ALL USES UNDER THIS GROUP NOT DISINFECTION REQUIRED TO ADDITION ONLY IF DISCHARGED INTO WATERS USED FOR THE GROWTH & PROPAGATION OF SHELLFISH, EITHER COMMERCIAL OR RECREATIONAL
E. AGRICULTURAL AND INDUSTRIAL WATER SUPPLY WITHOUT TREATMENT EXCEPT FOR THE REMOVAL OF NATURAL IMPURITIES TO MEET SPECIAL QUALITY REQUIREMENTS, OTHER THAN THOSE CLASSIFIED UNDER "A" ABOVE. NOTE: FOR AGRICULTURAL WATER SUPPLY, SALINITY AND SODIUM HAZARDS ARE DETERMINED BY ELECTRICAL CONDUCTIVITY ($EC \times 10^6$) AND SODIUM ADSORPTION RATIO (SAR). WATERS HIGH IN BOTH SALINITY AND SODIUM ARE GENERALLY UNSUITABLE FOR IRRIGATION PURPOSES. (SEE "CLASSIFICATION AND USE OF IRRIGATION WATERS", CIRCULAR NO. 969, U. S. DEPARTMENT OF AGRICULTURE, NOVEMBER, 1955)		SAME AS FOR USE "A" ABOVE	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH WILL ADVERSELY AFFECT THE MARKETABILITY OF AGRICULTURAL OR INDUSTRIAL PRODUCE	GREATER THAN THREE (3) PARTS PER MILLION	HYDROGEN ION CONCENTRATION EXPRESSED AS pH SHOULD BE MAINTAINED BETWEEN 6.0 & 9.5	SAME AS FOR USE "A" ABOVE	NONE IN SUFFICIENT QUANTITY AS TO MAKE RECEIVING WATER UNSUITABLE FOR USE INDICATED	SAME AS FOR USE "B" ABOVE	SAME AS FOR USE "A" ABOVE	SEDIMENTATION AND EFFECTIVE DISINFECTION

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See the following pages
for greater detail.
XXXXXXXXXXXXXXXXXXXX

Adopted by
POLLUTION CONTROL COUNCIL
PACIFIC NORTHWEST AREA
May 1952

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WATER QUALITY OBJECTIVES AND MINIMUM TREATMENT

WATER QUALITY → / WATER USES ↓	WATER QUALITY OBJECTIVES, APPLICABLE TO RECEIVING WATERS, FOR SALT AND FRESH SURF WATERS						
	ORGANISMS OF THE COLIFORM GROUP	FLOATING, SUSPENDED & SETTLEABLE SOLIDS & SLUDGE DEPOSITS	TASTE-OR ODOR-PRODUCING SUBSTANCES	DISSOLVED OXYGEN	pH	TOXIC, COLORED, OR OTHER DELETERIOUS SUBSTANCES	F CO
A. WATER SUPPLY, DRINKING, CULINARY & FOOD PROCESSING WITHOUT TREATMENT OTHER THAN SIMPLE DISINFECTION AND REMOVAL OF NATURALLY PRESENT IMPURITIES	MOST PROBABLE NUMBER COLIFORM BACTERIAL CONTENT OF A REPRESENTATIVE NUMBER OF SAMPLES SHOULD AVERAGE LESS THAN 50 PER 100 ML. IN ANY MONTH	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES OR OTHER WASTES OR WHICH, AFTER REASONABLE DILUTION & MIXTURE WITH RECEIVING WATERS, INTERFERE WITH THE BEST USE OF THESE WATERS FOR THE PURPOSE INDICATED	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES	GREATER THAN FIVE (5) PARTS PER MILLION EXCEPT FOR UNDERGROUND WATERS	HYDROGEN ION CONCENTRATION EXPRESSED AS pH SHOULD BE MAINTAINED BETWEEN 6.5 & 8.5	NONE ALONE OR IN COMBINATION WITH OTHER SUBSTANCES OR WASTES IN SUFFICIENT AMOUNTS OR OF SUCH NATURE AS TO MAKE RECEIVING WATER UNSAFE OR UNSUITABLE FOR USE INDICATED (U.S.P.H.S. STDS.)	LESS T PARTS
B. WATER SUPPLY, DRINKING, CULINARY & FOOD PROCESSING WITH TREATMENT EQUAL TO COAGULATION, SEDIMENTATION, FILTRATION, DISINFECTION AND ANY ADDITIONAL TREATMENT NECESSARY FOR REMOVING NATURALLY PRESENT IMPURITIES	M.P.N. COLIFORM BACTERIAL CONTENT WHEN ASSOCIATED WITH DOMESTIC SEWAGE OF A REPRESENTATIVE NUMBER OF SAMPLES SHOULD AVERAGE LESS THAN 2000 PER 100 ML. AND SHOULD NOT EXCEED THIS NUMBER IN MORE THAN 20 PER CENT OF SAMPLES EXAMINED IN ANY MONTH	SAME AS FOR USE "A" ABOVE	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH, AFTER REASONABLE DILUTION & MIXTURE, WILL INCREASE THE THRESHOLD ODOR NUMBER ABOVE NINE (9)	GREATER THAN FIVE (5) PARTS PER MILLION EXCEPT FOR UNDERGROUND WATERS	SAME AS FOR USE "A" ABOVE	SAME AS FOR USE "A" ABOVE	LESS T PARTS
C. BATHING, SWIMMING AND RECREATION NOTE: WHEN WATERS ARE USED FOR RECREATIONAL PURPOSES SUCH AS FISHING & BOATING, EXCLUSIVE OF BATHING & SWIMMING, THE NUMBER "1000" MAY BE SUBSTITUTED FOR "240" IN STATEMENT OF COLIFORM OBJECTIVE	COLIFORM BACTERIAL CONTENT OF A REPRESENTATIVE NUMBER OF SAMPLES SHOULD AVERAGE LESS THAN 240 PER 100 ML. AND SHOULD NOT EXCEED THIS NUMBER IN MORE THAN 20 PER CENT OF SAMPLES EXAMINED WHEN ASSOCIATED WITH DOMESTIC SEWAGE (SEE NOTE UNDER "C" AT LEFT)	SAME AS FOR USE "A" ABOVE	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH, AFTER REASONABLE DILUTION & MIXTURE, WILL INTERFERE WITH THE BEST USE OF THESE WATERS FOR THE PURPOSE INDICATED	GREATER THAN FIVE (5) PARTS PER MILLION	SAME AS FOR USE "A" ABOVE	SAME AS FOR USE "A" ABOVE	LESS PER M IN SUF AMOUN IMPART TASTE TIONAL FISH, OTHER
D. GROWTH & PROPAGATION OF FISH, SHELLFISH & OTHER AQUATIC LIFE	COLIFORM BACTERIAL CONTENT OF A REPRESENTATIVE NUMBER OF SAMPLES SHOULD NOT HAVE A MEDIAN CONCENTRATION GREATER THAN 70 PER 100 ML. IN WATERS USED FOR THE GROWTH & PROPAGATION OF SHELLFISH	SAME AS FOR USE "A" ABOVE	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH WILL INTERFERE WITH THE MARKETABILITY OR PROPAGATION OF RECREATIONAL OR COMMERCIAL FISH, SHELLFISH, OR OTHER EDIBLE AQUATIC FORMS	GREATER THAN SIX (6) PARTS PER MILLION	SAME AS FOR USE "A" ABOVE	NONE ALONE OR IN COMBINATION WITH OTHER SUBSTANCES OR WASTES TO SUFFICIENT AMOUNT OR OF SUCH CHARACTER AS TO MAKE RECEIVING WATERS UNSAFE OR UNSUITABLE FOR USE INDICATED	SAME A ABOVE
E. AGRICULTURAL AND INDUSTRIAL WATER SUPPLY WITHOUT TREATMENT EXCEPT FOR THE REMOVAL OF NATURAL IMPURITIES TO MEET SPECIAL QUALITY REQUIREMENTS, OTHER THAN THOSE CLASSIFIED UNDER "A" ABOVE. NOTE: FOR AGRICULTURAL WATER SUPPLY, SALINITY AND SODIUM HAZARDS ARE DETERMINED BY ELECTRICAL CONDUCTIVITY ($Ec \times 10^6$) AND SODIUM ADSORPTION RATIO (SAR). WATERS HIGH IN BOTH SALINITY AND SODIUM ARE GENERALLY UNSUITABLE FOR IRRIGATION PURPOSES. (SEE "CLASSIFICATION AND USE OF IRRIGATION WATERS", CIRCULAR NO. 969, U. S. DEPARTMENT OF AGRICULTURE, NOVEMBER, 1955)		SAME AS FOR USE "A" ABOVE	NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH WILL ADVERSELY AFFECT THE MARKETABILITY OF AGRICULTURAL OR INDUSTRIAL PRODUCE	GREATER THAN THREE (3) PARTS PER MILLION	HYDROGEN ION CONCENTRATION EXPRESSED AS pH SHOULD BE MAINTAINED BETWEEN 6.0 & 9.5	SAME AS FOR USE "A" ABOVE	NONE QUANTI RECEIV UNSUIT INDIC

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PLICABLE TO RECEIVING WATERS, FOR SALT AND FRESH SURFACE WATERS AND UNDERGROUND WATERS							MINIMUM TREATMENT REQUIREMENTS FOR DOMESTIC SEWAGE
TASTE-OR ODOR-PRODUCING SUBSTANCES	DISSOLVED OXYGEN	pH	TOXIC, COLORED, OR OTHER DELETERIOUS SUBSTANCES	PHENOLIC COMPOUNDS	OIL	HIGH TEMPERATURE WASTES	
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NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH, AFTER REASONABLE DILUTION & MIXTURE, WILL INCREASE THE THRESHOLD ODOR NUMBER ABOVE EIGHT (8)	GREATER THAN FIVE (5) PARTS PER MILLION EXCEPT FOR UNDERGROUND WATERS	SAME AS FOR USE "A" ABOVE	SAME AS FOR USE "A" ABOVE	LESS THAN FIVE (5) PARTS PER BILLION	NONE ALONE OR IN COMBINATION WITH OTHER SUBSTANCES OR WASTES AS TO MAKE RECEIVING WATER UNFIT OR UNSAFE FOR THE USE INDICATED	SAME AS FOR USE "A" ABOVE	SEDIMENTATION AND EFFECTIVE DISINFECTION
NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH, AFTER REASONABLE DILUTION & MIXTURE, WILL INTERFERE WITH THE BEST USE OF THESE WATERS FOR THE PURPOSE INDICATED	GREATER THAN FIVE (5) PARTS PER MILLION	SAME AS FOR USE "A" ABOVE	SAME AS FOR USE "A" ABOVE	LESS THAN 25 PARTS PER BILLION OR NONE IN SUFFICIENT AMOUNTS SUCH AS TO IMPART A RESIDUAL TASTE TO RECREATIONAL OR COMMERCIAL FISH, SHELLFISH, OR OTHER AQUATIC FORMS	SAME AS FOR USE "B" ABOVE	SAME AS FOR USE "A" ABOVE	SEDIMENTATION AND EFFECTIVE DISINFECTION
NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH WILL INTERFERE WITH THE MARKETABILITY OR PROPAGATION OF RECREATIONAL OR COMMERCIAL FISH, SHELLFISH, OR OTHER EDIBLE AQUATIC FORMS	GREATER THAN SIX (6) PARTS PER MILLION	SAME AS FOR USE "A" ABOVE	NONE ALONE OR IN COMBINATION WITH OTHER SUBSTANCES OR WASTES TO SUFFICIENT AMOUNT OR OF SUCH CHARACTER AS TO MAKE RECEIVING WATERS UNSAFE OR UNSUITABLE FOR USE INDICATED	SAME AS FOR USE "C" ABOVE	SAME AS FOR USE "B" ABOVE	NONE IN SUFFICIENT QUANTITY AS TO BE INJURIOUS TO OR INTERFERE WITH THE NORMAL PROPAGATION OF FISH, SHELLFISH, OR OTHER AQUATIC LIFE	SEDIMENTATION FOR ALL USES UNDER THIS GROUP BUT DISINFECTION REQUIRED IN ADDITION ONLY IF DISCHARGED INTO WATERS USED FOR THE GROWTH & PROPAGATION OF SHELLFISH, EITHER COMMERCIAL OR RECREATIONAL
NONE ATTRIBUTABLE TO SEWAGE, INDUSTRIAL WASTES, OR OTHER WASTES WHICH WILL ADVERSELY AFFECT THE MARKETABILITY OF AGRICULTURAL OR INDUSTRIAL PRODUCE	GREATER THAN THREE (3) PARTS PER MILLION	HYDROGEN ION CONCENTRATION EXPRESSED AS pH SHOULD BE MAINTAINED BETWEEN 6.0 & 9.5	SAME AS FOR USE "A" ABOVE	NONE IN SUFFICIENT QUANTITY AS TO MAKE RECEIVING WATER UNSUITABLE FOR USE INDICATED	SAME AS FOR USE "B" ABOVE	SAME AS FOR USE "A" ABOVE	SEDIMENTATION AND EFFECTIVE DISINFECTION

Adopted by
POLLUTION CONTROL COUNCIL
PACIFIC NORTHWEST AREA
May 1952
1st Revision Oct. 1956
2nd Revision
3rd Revision

Members of the Pollution Control Council have effectively used these water quality objectives since their adoption in 1952 in carrying out their individual pollution control programs. In recent years Montana and Idaho have formally adopted comparable objectives to guide their State programs. Oregon and Washington, together with the U. S. Public Health Service, have adopted an action program on the interstate boundary waters of the Lower Columbia River in keeping with these objectives. Similarly, Oregon and Washington have consistently aimed their programs at the goal established in this document.

The Water Pollution Control Advisory Board has reviewed and concurred with the following recommendations of the National Conference on Water Pollution which are pertinent to this manual:

(1) Goal of Pollution Abatement. The goal of pollution abatement is to protect and enhance the capacity of the water resource to serve the widest possible range of human needs. This goal can be approached only by accepting the positive policy of keeping waters as clean as possible, as opposed to the negative policy of attempting to use the full capacity of water for waste assimilation.

(2) A National Credo. The adoption of a suggested national credo should be given as wide and consistent publicity as is feasible. The content of the credo should include the following basic concepts: (a) users of water do not have an inherent right to pollute; (b) users of public waters have a responsibility for returning them as nearly clean as is technically possible; and (c) prevention is just as important as control of pollution.

(3) Comprehensive River Basin Development. Planning for the comprehensive development of each major basin or water resource area should be established as State and national policies. By comprehensive development we mean the application of integrated multiple-purpose design, planning, and management, which include the joint consideration of ground and surface waters and systematic conservation by water users.

(4) Recreation as a Full Partner with Other Use Interests. Public policy should formally recognize the recreation value of our water resources as a full partner with domestic, industrial, and agricultural values in water quality management policies and programs.

(5) Strengthening of State Programs. State statutes and organizational structures for water pollution control should be reviewed, revised and strengthened where necessary.

Watershed Management Objectives

Adequate watershed management accomplishes the following aims:

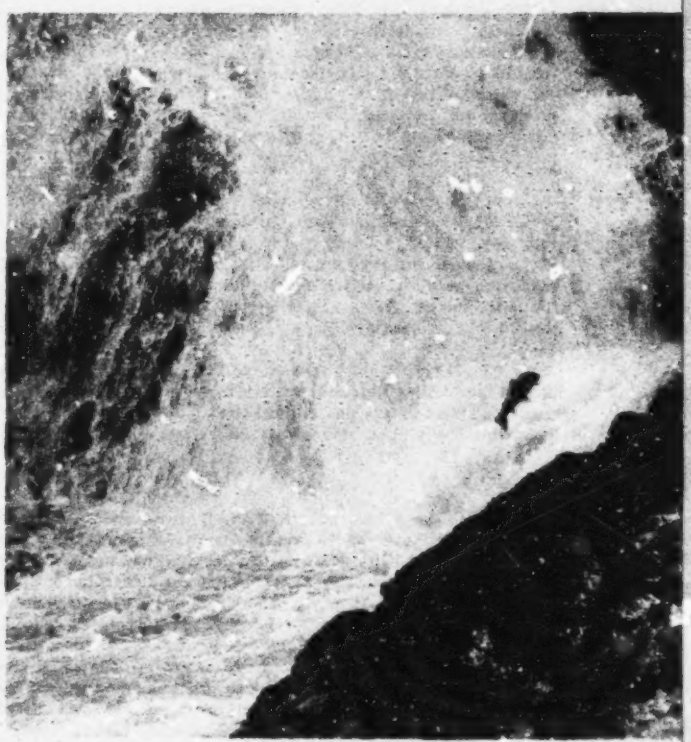
(1) Maintain the hydrologic balance between soil, water and plants to obtain optimum functioning of the watershed;

(2) Promote favorable conditions of streamflow, including both the seasonal distribution of flow and the reduction of flood discharges;

(3) Restore, maintain, and improve total water yields;

(4) Reduce to a minimum stream turbidity and sediment content, and by so doing maintain and improve desirable physical, chemical, and bacterial quality of the waters.

These objectives should be sought in every watershed. Though local needs and changing impacts from land use may influence the degree to which objectives may be attained, the maximum in reasonable measures should always be taken to preserve and maintain stream quality. For basin-wide programs the objectives must be based on the availability of water considering both quantity and quality, on water uses and demands, and on the water quality essential to full development and maintenance of those uses.



Salmon and steelhead need clean streams for spawning

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Policies and Legal Requirements

STATE AGENCY POLICIES

Alaska

The public policy of the State is to maintain reasonable standards of purity of the waters consistent with public health and public enjoyment, the propagation and protection of fish and wildlife, including birds, mammals and other terrestrial and aquatic life, and industrial development, and to that end require the use of all known available and reasonable methods to prevent and control the pollution of the waters.

Construction of any form of hydraulic project or use of any equipment that will use, divert, obstruct, pollute or change the natural flow or bed of any river, lake or stream, or to use, except for the purpose of crossing a river or stream at an established crossing, any wheeled, tracked or excavating equipment or log dragging equipment in the bed of any river, lake or stream containing anadromous fish or that will utilize any of the waters of the State or materials from any river, lake or stream bed is subject to approval by the Commissioner of Fish and Game conditioned upon proper protection of fish and game. Works in violation are declared a public nuisance and are subject to abatement and restoration of the original conditions of the river, lake or stream affected.

Idaho

Policy of the State Board of Health provides for an orderly and economically feasible comprehensive water pollution control program to conserve the waters of the State for all legitimate beneficial uses, including domestic, agricultural, industrial, recreational, and fish and wildlife propagation. Wastes discharged to surface and underground waters shall be treated so that they do not create a health hazard or nuisance and shall not impair the quality or interfere with the treatment processes of any public water supply. Plans for waste treatment and sewage facilities must be approved by the State Department of Health.

It is unlawful to deposit or permit to pass into any stream or lake any sawdust, chemicals, or other substances that may tend to the destruction or driving away of any fish. Settling ponds are required for discharges from quartz mills or reduction works to prevent deleterious chemicals from flowing into streams or lakes, and plans for settling ponds are subject to approval by the Fish and Game Department.

Leaving animal carcasses within a quarter-mile of any stream, or burying carcasses where they may pollute and make unfit for domestic use any natural stream or water in any canal or ditch or flume used for domestic purposes is a misdemeanor.

Montana

It is the public policy of the State to conserve the waters of the State and to protect, maintain and improve the quality and potability thereof for public water supplies, for the propagation of wildlife, fish and aquatic life, and for agricultural, industrial, recreational and other legitimate beneficial uses, to provide a comprehensive program in the public interest for the prevention, abatement and control of new or existing water pollution, to provide effective means for the carrying out and enforcement of such program, and to provide for cooperation with agencies of other States and the Federal government in carrying out these objectives.

Industrial waste is defined as any liquid, gaseous, or solid wastes substance resulting from any process of industry, manufacturing, trade or business or from the development of any natural resource, together with such sewage as may be present, which may pollute the waters of the State. Other wastes are defined to include garbage, municipal refuse, decayed wood, sawdust, shavings, bark, lime, sand, ashes, offal, night soil, oil, tar, chemicals and all other substances which may pollute the waters of the State. Pollution is defined as alteration of the physical, chemical or biological properties of any waters of the State which render said waters harmful or detrimental for their most beneficial uses.

Policy of the Fish and Game Department is to manage the lands and waters under its jurisdiction to provide a maximum of public benefits in harmony with good watershed management, to allow only such uses as will safeguard the yield and quality of waters, to cooperate with other State and Federal and local agencies, as well as with private landowners in carrying out mutually beneficial programs for water management, watershed protection and flood control.

Policy of the State Forester is to conduct the management of the forest, grazing and recreation resources and the fire and pest control activities on the lands within its jurisdiction in such manner as to prevent and avoid unnecessary watershed damage and stream pollution. In connection with sawmill operation, no person shall dump or deposit any sawdust, bark, shavings, ashes, cinders or other sawmill wastes in or near any stream, pond, lake or river, in such manner or place as will likely result or cause the same to be carried into the waters of any such stream, pond, lake or river.

Oregon

It is the public policy of the State of Oregon to: (a) maintain reasonable standards of purity of the water of all rivers, streams, lakes, watersheds and coastal areas of the State consistent with protection and conservation of public health, recreational enjoyment, economic and industrial development of the State, and plant and animal life; and (b) foster and encourage the cooperation of the people, industries, incorporated cities and towns and counties in preventing and controlling pollution of water.

The discharge into waters named above of any sewage or other waste which is or may become detrimental or injurious to human, plant, animal or aquatic life, or to recreational enjoyment of the people, by any person, firm, association or corporation, whether public, municipal, or private, or by any State-owned institution or industry, is declared to be not a reasonable or natural use of such waters, and contrary to public policy. In order to carry out this public policy, action shall be taken to abate existing pollution; to encourage cooperation in preventing, controlling and reducing pollution, and to require the use of all available and reasonable methods necessary.

Sawdust and other lumber wastes, slashings from trees or brush, oil, coal, petroleum products, dyes and chemicals are specifically prohibited.

No substance shall be discharged into the waters that will cause: (1) oxygen content of waters to drop below 5 ppm, (2) pH to rise above 8.5 or drop below 6.5, (3) liberation of gases harmful to aquatic life, (4) development of fungi or other growths injurious to health, recreation or industry, (5) creation

of toxic conditions, (6) formation of appreciable sludge deposits, (7) objectionable discoloration or turbidity or scum or oil films, or (8) bacterial pollution.

Licenses for dredging operations (any dredge mining operation, except industrial mineral or sand and gravel production, which substantially disturbs more than 15 acres per year of the topsoil or ground cover of the land, if the land constitutes the floor of a valley) are conditioned upon:

(a) Replacing the topsoil and ground cover disturbed and restoring the area to a reasonably useful condition;

(b) Replacing any stream disturbed with a pool structure conducive to good fish habitat and recreational use; and

(c) Constructing settling ponds of sufficient capacity and character to remove silt caused by the dredging before the water is discharged into a stream.

No substance shall be allowed to escape into or be deposited in any public waters that will in any way injuriously affect the life, growth or flavor of oysters or other shellfish in or under such waters.

Washington

The State of Washington has declared the following public policies with respect to water quality and quantity:

Water Quality

(a) The public policy of the State of Washington is to maintain the highest possible standards to insure the purity of all waters of the State consistent with public health and public enjoyment thereof, the propagation and protection of wildlife, birds, game, fish and other aquatic life, and the industrial development of the State, and to that end require the use of all known available and reasonable methods by industries and others to prevent and control the pollution of the waters of the State of Washington.

(b) The public waters of the State include lakes, rivers, ponds, streams, inland waters, underground waters, salt waters and all other surface waters and water courses within the jurisdiction of the State of Washington.

(c) The statutes of the State declare it shall be unlawful for any person to throw, drain, run, or otherwise discharge or allow to seep into any of the waters of the State any organic or inorganic matter that shall cause or tend to cause a polluted condition of such waters.

Water Quantity

(a) The declared public policy of the State with reference to low stream flows is that a flow of water sufficient to support game fish and food fish populations be maintained at all times in the streams of the State.

(b) The Departments of Fisheries and Game are concerned with changes or diversions in natural stream channels and, consequently, any form of hydraulic or other project that will use, divert, change or obstruct the natural flow or bed of any river or stream, or that will utilize any of the waters of the State or materials from the stream beds, is subject to approval of the directors of fish and game conditioned upon provisions for proper protection for fish life.

(c) In order to protect stream channels and flows on forested lands, representatives of the Departments of Fisheries and Game have the right to review the logging permits issued by the Department of Natural Resources. Letters are subsequently sent to logging permittees advising them of the State requirements regarding stream protection and offering advisory service. This method has been helpful in obtaining compliance with State law and in protecting streams and fish habitat.

BRITISH COLUMBIA

The policy of the Province of British Columbia is to prevent any pollution of the waters of the Province where such pollution might harm any beneficial use of the water.

The main Act dealing with water in British Columbia is the "Water Act" which is administered by the Comptroller of Water Rights. Under this Act, with a few minor exceptions, all surface waters belong to the Crown in the right of the Province. Licenses may be issued to private persons and corporations for the use, diversion, or storage of water. Conditions may be written into any license for the prevention of pollution. Also under this Act it is an offense against the Act for any person to put "into any stream any sawdust, timber, tailings, gravel, refuse, carcass, or other thing or substance after having been ordered by the Engineer or Water Recorder not to do so."

The "Health Act", which is administered by the Minister of Health, also has strong powers to control pollution. Under this Act, no person may construct a sewerage system (including sewage treatment plants and outfalls) without having first submitted to and obtained the approval of the Minister, plans, specifications, and engineers' reports governing such construction. The Minister has the right to require alterations in such plans and specifications before approval. The Minister also has the right to require treatment or additional treatment of sewage whenever in the opinion of the Minister such is necessary to protect the public health. Also, in Regulations passed under authority of the "Health Act", a local (municipal) Board of Health has authority to prevent pollution of streams within its own jurisdiction. Also, under other Regulations passed pursuant to the "Health Act", certain specific regulations may be made to apply on watersheds which are municipal water supply sources.

Under the "Pollution Control Act" which was passed in 1956, a Pollution Control Board is set up to administer pollution control measures in the Lower Fraser Basin, and, since April 1st, 1961, in the British Columbia portion of the Columbia Basin. The technical work of this Board is performed by the Health Department. Under this Board, the right to discharge effluents of any kind may be obtained only by a permit from the Pollution Control Board. Any person wishing to discharge effluent of any kind into the waters under the jurisdiction of the Board must submit a formal application to the Board, must post a copy of the application on the site of the proposed outfall, and must advertise the application in newspapers and in the British Columbia Gazette. In the permit issued, the Pollution Control Board sets out the maximum allowable concentrations of any item that may be discharged. The technical work of the Pollution Control Board is performed by the Health Department.

There are other Provincial agencies which have some part to play in pollution control. The Department of Recreation through its Park Branch has the right to prevent pollution of streams within parks through its Park by-laws. Also, through its Fish and Game Branch it has the right to take measures to prevent pollution that might affect sport fish or wildlife. The Forest Service through its issuance of timber sales, timber leases, forest management licenses, etc., has the right to write into the agreement conditions for the prevention of fouling of streams through certain logging practices. The appropriate public water supply or fishery or game agency is advised of the timber sale and its proposed conditions, and is given the opportunity to make comment.

FEDERAL AGENCIES

U. S. Department of Health, Education and Welfare (Public Health Service)

The Public Health Service operates under the Federal Water Pollution Control Act of 1956 (33 U.S.C. 466-466K) which provides for the development (in cooperation with other Federal agencies, with State water pollution control agencies and interstate agencies, and with the municipalities and industries involved) of comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary condition of surface and underground waters. In such comprehensive programs, due regard is given to water for public supplies, propagation of fish and aquatic life and wildlife, recreational purposes, and agricultural, industrial, and other legitimate uses. Interstate cooperation for the prevention and control of water pollution, toward improved and uniform State laws and compacts between States for the prevention and control of water pollution are specifically encouraged by the Act. Technical assistance, cooperation in research and training personnel of public agencies in technical matters relating to causes, prevention and control of water pollution are offered the States under the Act. Grants are also offered the States and interstate agencies to assist them in establishing and maintaining adequate measures for the prevention and control of water pollution; and to interstate agencies and municipalities for construction of necessary treatment works to prevent the discharge of untreated or inadequately treated sewage or other waste into any waters. The Act establishes a Water Pollution Control Advisory Board to advise and recommend on policy relating to activities under the Act. Further, the Act provides conditions under which the Secretary of Health, Education and Welfare can call a conference of the agencies concerned in any matter of pollution of interstate or navigable waters endangering the public health or welfare; that the Secretary shall, where effective progress toward abatement of such pollution is not being made, recommend the necessary remedial action to the appropriate State water pollution control agency, specify a reasonable time to secure abatement, and if action is not taken within the time specified, request the Attorney General to bring suit on behalf of the United States to secure abatement of the pollution.

The 1961 amendments to the Federal Water Pollution Control Act provide for field laboratory and research facilities and expanded research relating to waste treatment and prevention and control of water pollution; provide for increased program and construction grants to States to promote waste treatment and pollution abatement; and provide increased responsibility in enforcement of pollution control in interstate or navigable waters. The Water Supply Act of 1958, as amended in 1961, provides that studies be made on all water storage projects being planned by Federal agencies to determine and evaluate needs for storage for regulation of streamflow for the purpose of water supply and water quality control.

Responsibilities of the Public Health Service are to safeguard water resources for all legitimate uses, through the prevention and control of water pollution, with due regard for the responsibilities of State and other Federal agencies. The Public Health Service supports the State agencies in their water quality management and conservation programs. The value of soil conservation, sediment control, and salinity control as pollution abatement measures is recognized by the Public Health Service in its various activities.

Major programs of the Division of Water Supply and Pollution Control in the Public Health Service include: (1) a Basic Data program to collect, analyze, and disseminate data on public and industrial water supply facilities, water quality, causes of pollution, and techniques for control or prevention of pollution; (2) a Construction Grants program which administers, in collaboration with State water pollution control agencies, Federal grants for construction of municipal sewage treatment works authorized by the Federal Water Pollution Control Act; (3) an Enforcement program which encourages State and interstate abatement of water pollution and institutes action against such pollution under conditions prescribed by the Act; (4) a Research program aimed at developing knowledge and methods of solving the increasingly complex problems of water and waste treatment and stream sanitation, and at stimulating and supporting complementary research and development by others; (5) a Technical Services program which provides technical assistance and information in the solution of special water supply and pollution problems toward developing improved national water quality management practices designed to maintain adequate water quantity and quality for all beneficial uses, training in pollution control, comprehensive water resources studies in major river basins, and for cooperation with interagency, interstate, and international organizations concerned with development and protection of water resources.

U. S. Department of Agriculture (Forest Service)

General policy, according to Forest Service Manual, Code 2505, is that national forest uses will be modified to meet approved watershed management objectives whenever the existing or potential usefulness of water or control of runoff is jeopardized. It may be necessary to restrict entry or to modify or prohibit certain uses; but such action will be taken only to the extent necessary to safeguard water yields, water quality, and desirable characteristics of streamflow. Resource protection activities such as fire and pest control will be planned and conducted to avoid unnecessary watershed damage. Where restorative measures are needed to protect and improve the water resource, restoration projects will be planned and undertaken promptly.

The Forest Service will assist other Federal and State agencies, local Governmental units, and individuals in developing orderly and beneficial water storage, hydropower, and other similar projects. In doing this the guiding policy will be to reconcile proposed projects with the purposes for which the national forests are administered.

State water rights and antipollution laws and regulations will be recognized and followed in Forest Service programs. Also, the Forest Service will recognize and adhere to U. S. Public Health Service antipollution regulations.

The Forest Service will cooperate with Federal, State and local agencies and organizations, and with private landowners in programs of mutual interest for water management, watershed protection and flood prevention.

Forest Service logging contract clauses require that material from slides and other sources to be removed from roads shall not be deposited in streams or in locations where it will wash into streams and cause damage through silting of streams or reservoirs. No debris shall be placed in streams, streambeds, or lakes. Material deposited in any stream channel which in any way impairs the flow of the stream must be removed. All operations by the purchaser including road construction and the cutting and removal of timber shall be so conducted as to minimize damage to stream courses and streamsides. All practicable precautions shall be taken to minimize soil erosion and damage to the soil, including prevention of gullying of roads and skidtrails, protection of cover and soil and water in natural meadows, and refraining from operation of equipment when ground conditions are such that excessive damage will result. Avoidable or excessive soil damage shall be repaired as soon as practicable to prevent accelerated soil erosion. Care must be taken to avoid interference with the

natural flow of streams. Streams temporarily diverted must be restored to their natural courses as soon as practicable. On roads, skidtrails and firelines to be abandoned, temporary culverts will be removed, and cross ditches and water spreading ditches will be built. Revegetation of areas of unavoidable soil disturbance on road cut and fill slopes and on skidtrails susceptible to erosion will be done by seeding or planting with grass and other herbaceous or woody seed, seedlings, or cuttings. Operations must comply with State regulations concerning sanitation, maintain improvements in a clean sanitary condition, dispose of wastes in such manner as to prevent pollution of streams or lakes and to minimize breeding of flies. Sawdust and other mill refuse must not be permitted to enter any stream, lake or tidewater.

U. S. Department of Defense

The Corps of Engineers, U. S. Army, is a major construction agency concerned with improvements for navigation, flood control, hydroelectric power development and other water uses on streams of the Pacific Northwest. The planning and execution by the Corps of Engineers of civil works improvements to obtain the maximum sustained public benefits involves consideration of many water uses and problems other than navigation, flood control and development of hydroelectric power. Insofar as practicable, the plans of river improvement must provide for local and regional needs for pollution abatement; water supply for municipal, industrial and agricultural use; preservation of fish and wildlife, and recreation. The effect on the public health is an important consideration which runs through a number of these water uses and problems. In many cases the benefits which result from regulation of low water flows may equal or exceed the benefits from control of floods.

In its planning for development of the water resources of river basins the Corps of Engineers works closely with the Public Health Service and with appropriate State and local agencies where pollution problems are involved and it is apparent, in many cases, that civil works improvements can contribute substantially toward solving this problem. In times of natural low flow when pollution problems are the most aggravated, the increased flow furnished by a reservoir or system of reservoirs aids in diluting and aerating the pollutant and ameliorating the conditions. In planning reservoirs the Corps considers such requirements and, when feasible, arranges to maintain a flow in the stream below the dam adequate to meet the needs of pollution abatement, water supply and other water uses.

As the navigable waters of the United States are exploited by ever-increasing populations and industries of every nature, numerous abuses of these waterways by deposition of injurious matter, both from vessels and shore-side installations, occur either through wilfulness or the lack of knowledge as to existing law. From time to time it becomes necessary to call the attention of the public to the Federal law prohibiting the depositing of injurious substances in the navigable waters of the United States. This basic law is known as the River and Harbor Act of March 3, 1899. The specific section to which reference is made reads as follows: "Sec. 13. That it shall not be lawful to throw, discharge, or deposit or cause, suffer or procure to be thrown, discharged or deposited either from or out of any ship, barge or other floating craft of any kind or from the shore, wharf, manufacturing establishment, or mill of any kind, any refuse matter of any kind or description whatever other than that flowing from streets and sewers and passing therefrom in a liquid state into any navigable water of the United States or into any tributary of any navigable water from which the same shall float or be washed into such navigable water; and it shall not be lawful to deposit, or cause, suffer or procure to be deposited material of any kind in any tributary of any navigable water, where the same shall be liable to be washed into such navigable water, either by ordinary or high tides or by storm or floods or otherwise, whereby navigation shall or may be impeded or obstructed: Provided, That nothing herein contained shall extend to, apply to, or prohibit the operation in connection with the improvement of navigable waters or construction of public works considered necessary and proper by the United States officers supervising such improvement or public work: And provided further, that the Secretary of War, whenever in the judgment of the Chief of Engineers anchorage and navigation will not be injured thereby, may permit the deposit of any material above mentioned in navigable waters, within limits to be defined and under conditions to be prescribed by him, provided application is made to him prior to depositing such material; and whenever any permit is so granted the conditions thereof shall be strictly complied with and any violation thereof shall be unlawful."***

Section 3 of the Oil Pollution Act of 1924 provides that except in case of emergency imperiling life or property or unavoidable accident, collision, or stranding and except as otherwise permitted by regulations prescribed by the Secretary of the Army, it shall be unlawful for any person to discharge or suffer or permit the discharge of oil by any method, means or manner into or upon the coastal navigable waters of the United States from any vessel using oil as fuel for the generation of propulsion power or any vessel carrying or having oil thereon in excess of that necessary for its lubricating requirements and such as may be required under the laws of the United States and the rules and regulations prescribed thereunder.

With respect to disposal of sewage and other wastes from civil works projects and military installations, the Corps of Engineers collaborates closely with the Public Health Service and state authorities having jurisdiction over stream pollution control with a view to assuring that sewage treatment and disposal facilities meet the sanitary requirements of the state or states involved.

U. S. Department of The Interior

The Department of the Interior is concerned principally with the management, conservation, and development of natural resources. Its various agencies are charged with the responsibility of preventing waste, encouraging efficient use, providing adequate resource development to meet the requirements of the national economy and security, maintaining production capacity for future generations, and assuring an equitable distribution of benefits. Watershed protection and water quality maintenance play an important role in the overall program.

The objective of the Bureau of Land Management in managing watersheds on the national land reserve is to insure continued productive use now and maintained for future generations.

The National Park Service is responsible for the development and management of the areas in the National Park System. Through education, conservation practices, and operating policies it protects watersheds and other resources within the parks. It also cooperates with other Federal, State, and local agencies in formulating park programs and in planning parks and recreation areas.

The purpose of the National Parks is to conserve the scenery and the natural and historic objects and the wildlife, and provide for their enjoyment in such manner as will leave them unimpaired for the enjoyment of future generations. The basic fundamental is that the whole natural community, including the water resources, shall be subject to a minimum of human interference or manipulation and that there shall be a free play of natural forces and processes. National Park regu-

lations require that campers not wash clothing or cooking and eating utensils in, or pollute in any other manner, the waters of the parks and monuments; prohibit any contamination of watersheds or water supplies; and require that garbage, litter, and other wastes shall not be put into park waters but shall be disposed of on shore at designated locations by prescribed means.

The Bureau of Sport Fisheries and Wildlife is directly concerned with water management, preservation of water quality, protection of fish and wildlife habitat, prevention of pollution, and maintenance of minimum stream flows at levels adequate for fish and wildlife.

Operations of the Bureau of Reclamation, a construction and operating agency, are carried on as prescribed by applicable Federal and State laws. As a matter of policy, Bureau of Reclamation construction contractors are required to conduct their operations so as to minimize disturbance of streambeds and adverse effects upon natural surroundings.

Wherever authorized by the Congress as a part of the project works, facilities are provided in water control structures for protection and/or passage of fish, for wildlife and water fowl, for controlling flood flows, and for maintaining acceptable minimum downstream discharges within established State water laws.

The Bureau of Reclamation cooperates with water-user organizations in watershed management to minimize erosion and lessen subsequent deposition of silt in storage and diversion pools located on water courses.

GOVERNMENT OF CANADA

There are certain agencies of the Government of Canada which have responsibilities in pollution control in British Columbia.

The Department of Fisheries, through the "Fisheries Act" has authority to take action against any person or corporation polluting a stream in any manner that might affect the well-being of fishes. In practice, the Department of Fisheries advises the management of proposed new industries on the measures of pollution control that would satisfy them. There is good liaison between the Department of Fisheries and the Provincial Pollution Control Board in this regard.

Also, the Department of Northern Affairs and Natural Resources, which administers the "Migratory Birds Regulation Act", has authority to take action against any person polluting waters such as to affect the well-being of migratory birds.

The Department of Transport through the "Navigable Waters Protection Act" and the "Canada Shipping Act" has certain regulations for the prevention of discharges from ships or other sources that will harm shipping.

The Department of Public Works of Canada also has authority under the "Navigable Water Protection Act" to control structures such as sewage outfalls built in navigable waters. Also the National Harbours Board and certain local port authorities have powers derived from Federal legislation to prevent pollution that will harm shipping within their own jurisdiction.

Program Coordination, Cooperation, and Legislative Needs

One may readily note from the summaries of the State policies and requirements in the preceding section that there are a number of gaps and that there is not uniform protection for all areas. To provide complete protection to water and associated resources, State codes should cover siltation and turbidity caused by any human or non-natural activity, regardless of the type or extent of the operations involved. Even an operation of short duration, limited in area, and affecting a single stream may cause great damage to fisheries by siltation of many miles of spawning beds downstream from the operation.

Some of the State codes need to be strengthened, and the State agencies responsible for carrying out and enforcing provisions of the codes need to be strengthened. This is, of course, a task for the State legislatures. But the individual agencies often can strengthen their own operations and improve their effectiveness by increasing interagency liaison and communications. It may happen that the activities of one agency conflict with the interests of another; highway construction may disturb stream channels and add quantities of sediment to streamflow, or spraying for pest control may contaminate streamflow, and both operations may be strongly objected to by the fisheries and the public health agencies responsible for safeguarding water quality. Obviously, exchange of work plans and discussion of work methods and timing in advance of the work would avoid interagency friction and reduce possible damages to water and associated resources.

Similarly, Federal construction and land-managing agencies may also at times find their operations and interests in conflict. Again, improved liaison and communication regarding proposed work projects help avoid conflict and prevent damage to streams and water supplies.

Because of the primary right of the States to control water resources, the Federal agencies have an additional responsibility to see that their operations or permits to others, as well as their own water management programs, are in accord with State requirements and compatible with the water management programs and policies of the various States. Here again good liaison and communications between Federal and State agencies will greatly aid protection of water resources. If there appear to be gaps between what the Federal agencies can do under law and what they should be doing to provide full protection to water resources where operations on Federal lands are concerned, such simple devices as advance notification to the interested State agencies of any developments that may have an impact on water quality and water use can be very helpful. Though the States generally have police powers to enforce their responsibilities, these powers have historically been applied after the fact, after damage has been done. The principal concern of the States should be the prevention or avoidance of damage to water resources.

A number of interagency groups have been established to help solve these problems and to improve liaison and exchange of information. Several of the technical subcommittees of the Columbia Basin Inter-Agency Committee direct their

attention immediately to matters of protection of water resources; these have included the Water Supply and Pollution Control Subcommittee and its task force on sedimentation, the Alluvial Mining Subcommittee, the Debris Control Subcommittee, and the Mosquito Control Subcommittee. Others with less immediate concern include the Fisheries Subcommittee and the Recreation Subcommittee. One recent benefit from the interagency contacts and liaison has been the arrangement whereby the Federal land-managing agencies notify State fish and game and pollution control agencies of mining claims as they are received; this enables the interested State agency to get in touch with the claim operator and notify him in advance as to State requirements for stream protection.

Specific control measures that are useful in various situations follow. With these and the policies and views already described as guides, the Federal and State agencies may desire to investigate relationships in their own operations and enabling legislation to determine needed improvements in both.

Watershed Management Recommendations

PURPOSES

Protection of Water Quality and Public Health

Because the many activities and developments on a watershed may adversely affect quality of the water derived therefrom and the health of the users of that water, the recommendations to follow include specifications for controlling bacterial contamination and chemical pollution on producing watersheds. These recommendations serve the purpose of water quality protection and management. However, it should always be borne in mind that there is more to be gained through prevention or avoidance of the problem than through control or restoration after pollution and contamination have already happened. Thorough planning, which includes considerations of water quality protection whenever activities or developments on a watershed are undertaken, will serve to avoid troublesome situations, or to point up problems that require preventive or restorative measures for their solution.

Reduction of Flood Damage

Floods occur from natural causes, but flood peak size and amount of flood damage may be significantly affected by what land use and development have done to the contributing watershed. One of the purposes of the recommendations is to point out means of avoiding, preventing or controlling rapid runoff and accelerated erosion that increase flood peaks and flood debris loads, and avoiding the placement of floatable material where it can be picked up by streamflow. Some of the specifications are simple and obvious; it is necessary merely to see that they are considered and included in planning and operating various watershed activities. Others may add significantly to costs, but must be considered in analysis of benefits and desirability of any work undertaken on watershed lands or in stream channels.

Maintenance and Improvement of Fish and Game Habitat

Fish and game are an important part of the recreation "resource" that is more and more in demand in range and forest areas. Recommendations given with the aim of preserving water quality or of ameliorating flood and sediment conditions will be equally beneficial to fish and game habitat.

Improvement of Water Yield

The principal need is for maintenance or restoration of water quality, and most of the recommendations bear on that matter. However, since activities that affect watershed soil and cover also affect the amount and timing of streamflow, there is a potential for saving water and for stabilizing streamflow that should not be overlooked. Judicious watershed treatment can increase total water yield without increasing runoff and erosion and flood hazards. Research is needed to determine the best methods and the amount of yield to be gained in different climates with different types of cover, but some recommendations can be made from present knowledge.

SPECIFIC RECOMMENDATIONS

1. Construction Activities

The following recommendations cover only those phases of construction which, in the past, have been instrumental in causing serious damage to the water resources of the Pacific Northwest. Most of the public agencies and private groups responsible for construction projects have found that the control of soil erosion during and after construction pays off in reduced construction and maintenance costs. However, contractors take many shortcuts which often create conditions unfavorable to the maintenance of water quality. Control of operations should be adequate to assure that turbidity in the river water will not be increased to more than 10 ppm or other locally established limitation in streams used for public water supply. In streams used for other purposes, the increase in turbidity should be kept below 50 ppm. Accordingly, specifications prepared for both public and private construction should include the following minimum requirements wherever practicable.

a. Road and Railroad Construction

(1) Location Surveys

During preliminary and final location surveys, consideration should be given to:

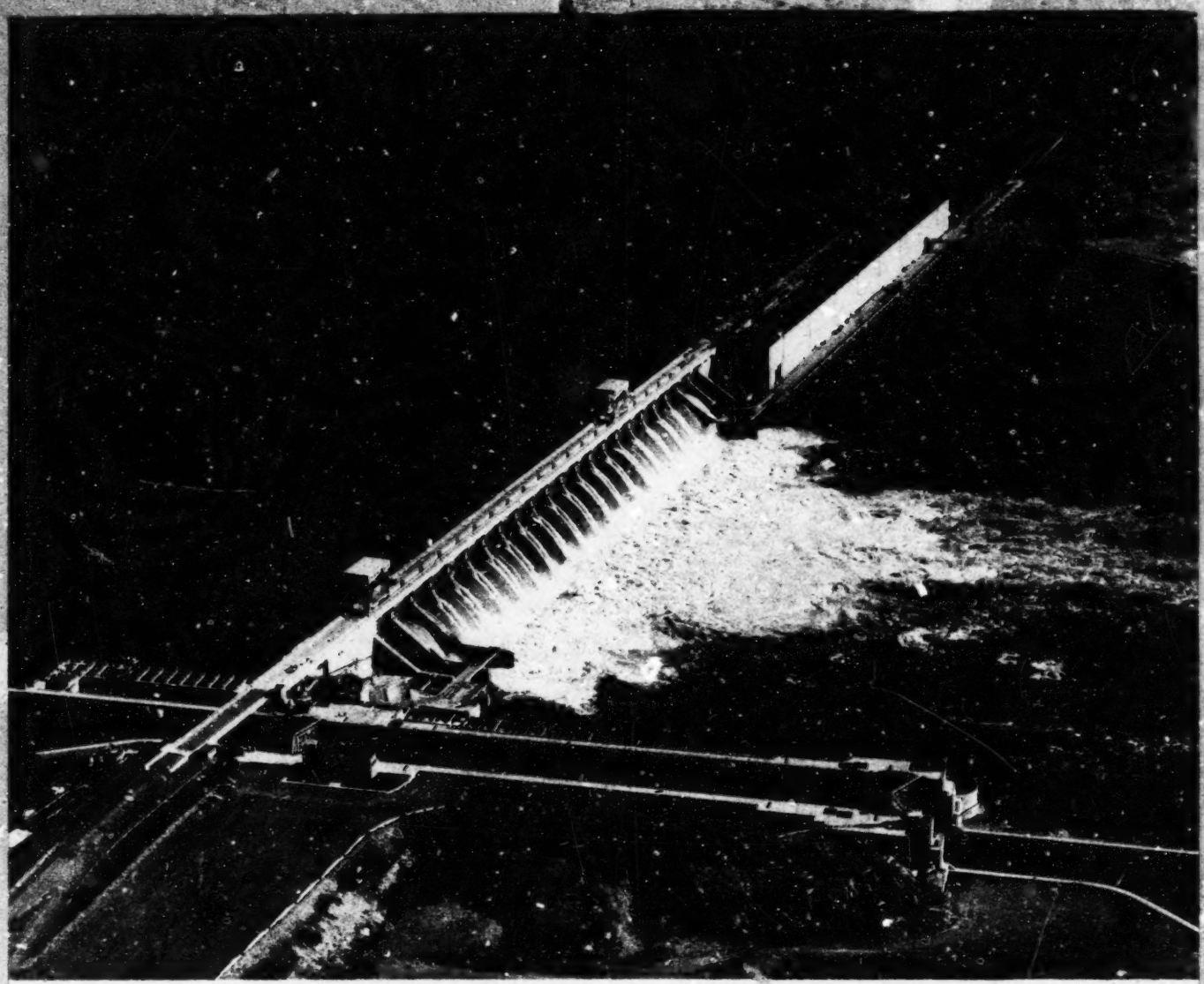
Keeping roads away from natural drainage channels. Bench locations should be used as much as possible; and optimum gradient may occasionally be sacrificed to gain a safe location. (This refers particularly to logging and temporary access roads).

The selection of stream crossing points which will involve a minimum of disturbance to banks and existing channels.

The avoidance of excessive cuts and waste dirt accumulations near natural drainages.

(2) Construction Equipment

Special precautions such as seepage pits or other confinement measures should be taken to prevent diesel oil, fuel oil and other substances from being washed into streams.



McNary Dam from the Washington Side, a major step in harnessing the mighty Columbia. Ship locks in foreground; fish ladder on the far end of the structure.

Oil transportation facilities should make use of drip collectors and provisions should be made to collect and dispose of accidental spills.

Drainage from construction areas should be collected and diverted away from streams. Gravel wash waters should receive adequate clarification prior to discharge to a stream.

(3) Road Bed Construction

Construction activities which cause a direct conflict with a water resource use may have to be completed at the time of least interference.

Rough grading should normally be carried no further than can be completely finished during a current season. Each section graded should be fully backsloped, have drainage installed and ditches finished before another section is opened up, particularly toward the end of the season. Dry weather construction will reduce the effects of soil disturbances.

On sidehills and near channel crossings, road drainages should discharge where sediment can settle out before reaching a stream channel.

Excess dirt from cuts should never be deposited directly in a flowing stream and should be kept above the high water level of the channel. End-hauling to safe bench or cove locations should be used. Waste dirt should be stabilized against erosion and slumping and should not drain directly to stream channels.

Large cut slopes in critical slump areas should be graded 1-3/4 to 1 or flatter, and adequate drainage measures should be installed. Soil stabilization measures such as matting, terracing, compacting, mulching, and planting with grass or shrubs should be used in critical areas.

Large fill areas should be protected by adequate surface drainage diversion systems, and stabilized as noted preceding.

On some dirt roads it will be necessary to build up the surface with rock to prevent mud and turbid waters from draining from the roadbed to a nearby stream.

Surface drainages from cuts and fills and from borrow and waste disposal areas should be collected in suitable ponding areas if the soils are such as to produce excessive turbidity. Drainage should be diverted or otherwise handled so as not to pass over or collect in new cuts, fills, borrow areas and waste areas.

(4) Bridges and Culverts

Bridges or culverts should be provided at all natural watercourses both for permanent and temporary access or haul roads.

Culverts should be placed without excessive channel disturbance and fill materials should be kept away from culvert inlets and outlets.

Permanent culvert sizes should be large enough to carry a ten-year flood and should not be less than 18 inches in diameter.

Culverts should be set on the natural slope and should be extended well beyond the fill slopes. If this is not practical, head walls should be used. "Cannon" culverts projecting from steep slopes and having unprotected outfalls should not be used.

Large culverts should be designed in accordance with fishery department standards in order to allow for the passage of migratory fishes.

The maximum spacing of culverts should be governed by the road gradient and by the type of soils, and may range from 200 feet to approximately 1200 feet.

Large culvert inlets should be inspected and cleaned, if necessary, prior to and during the annual rainy season so as to prevent clogging and possible washouts.

Riprap or abutments should be used to stabilize fill materials or disturbed soils at bridge approaches. In bridge location avoid channel relocation as far as possible.

In domestic water supply watersheds, railroad bridges should have solid decks with drainage away from streams.

(5) Post-Construction and Maintenance

Periodic inspection should be made of all completed cut and fill areas to determine the effectiveness of soil erosion and stabilization measures and to determine whether or not additional precautionary measures are necessary.

Drainage diversions need to be checked and maintained regularly.

b. Power Transmission Lines

Specifications included in Section 1a. above should be followed in the location, construction and maintenance of roads used for access to areas for construction and/or maintenance purposes. Roads not required after construction should be drained, mulched and seeded or planted for stabilization before being abandoned.

Trees should be removed from the area by approved logging methods as specified in Section 4c. following. Land from which trees and other vegetation is removed should be seeded or planted with a type of vegetation which will not interfere with the overhead lines but which will stabilize the soil.

Soil excavated for tower footings should be placed so that it will not be washed into the stream during storms and should be leveled so that all disturbed areas can be seeded upon completion of construction.

c. Dams

Overburden removed from borrow pits should be placed in such a manner as to minimize the washing of excavated materials into the watercourse during rainy periods. Where necessary to pump or drain water from the excavated area, it should be disposed of by spreading on soil covered by vegetation or by other means which will limit the amount of the turbid water reaching the watercourse. Before abandoning borrow pits located outside the reservoir area, all soil in the spoils banks should be replaced in the excavated area, smoothed and stabilized by seeding or other means.

If at all possible, sand and gravel or stone for crushing should be obtained from areas other than the stream bed itself. Where necessary to obtain aggregate from the bed of the stream, the section or sections being worked should be dammed off or secured in accordance with territorial, state or provincial regulations where applicable. Before any wash water is discharged, it should be clarified sufficiently to assure that turbidity in the river water will not be increased to more than 10 parts per million or other locally established limitation in streams used for public water supply or for salmon, trout or steelhead spawning. In streams used for other purposes, the turbidity should be kept below 50 ppm for normal streamflow. A closed system wherein none of the wash water is discharged to a stream is preferred. Where wash water is to be discharged to a stream, suspended wastes should be removed by impounding, coagulation and sedimentation, or other acceptable methods which will meet the above criteria. Season of operation may be important; the spawning and rearing season for the young fry being July - January in most areas.

Tanks and container areas used to store fuel, oils, chemicals and toxic substances should be protected from leakage by construction of dikes around the tanks to catch any liquid losses.

Concrete and aggregate plants should be inspected frequently to assure that wastes will not accumulate in locations where drainage to the watercourse cannot be controlled.

Specifications included in Section 1a. above should be followed in the relocation of roads and railroads and construction and maintenance of access roads.

Specifications included in Section 4c. below should be followed in clearing of reservoir areas. Complete clearing and removal of all floatable debris from reservoir flowage areas is strongly recommended.

d. Construction Camps and Crews

(1) Definition

Construction camps are considered to be facilities providing housing and feeding for personnel and serving for the duration of a specific construction activity. Equipment

maintenance and office facilities are sometimes provided at the same or other locations. Construction and maintenance crews working in watersheds are those transported to the point of work from a central camp or headquarters.

(2) Location

Where the construction activity is on a domestic water supply watershed yielding high quality water requiring no treatment except disinfection, the construction camp should be located completely out of the watershed, unless over-riding factors can be shown to dictate otherwise. When they must be on the watershed, domestic or otherwise, they should be located as remotely as possible from the main stream and any of its tributaries so as to eliminate or minimize any effect upon the water. They should be located on land having topography which will have a minimum of erosion due to rainfall and snowmelt.

(3) Approvals

Any installation, operation and methods of sanitary waste disposal facilities should meet the requirements of and be approved by the health department having jurisdiction and by the owners of the water supply if involved.

(4) Facilities for Waste Disposal

(a) For use on domestic water supply watersheds yielding high quality water requiring no treatment except disinfection.

1. Body waste

Provide portable waste containers for disposal outside of watershed at a point approved by appropriate local jurisdiction. This type consists of containers such as oil drums which should be removed from the watershed as necessary and the drum and contents buried or the drum cleaned and contents buried at designated locations approved by health authorities. Reusable tops equipped with seats and self-closing covers are preferred. Chemicals for odor and fly control should be required to ensure that the facilities will be used. At the point of disposal by burial, a disinfectant may be necessary as required by local authority.

2. Garbage and other refuse

All garbage and other refuse should be stored in covered, sanitary, waterproof, metal containers except that dry refuse, such as clean paper cartons, may be stored separately. Containers and the area of storage should be so located and kept clean to minimize fly population, odors and rodents. The contents should be removed at frequent intervals from the watershed to an approved point of burial or for pickup by commercial haulers. At an approved point of burial, use trench and fill or other sanitary fill method, compact the material and cover with a minimum of 18 inches compacted fill dirt daily. Dry refuse should be removed from the watershed regularly, buried within the watershed at an acceptable point of disposal, or incinerated if fire regulations permit.

3. Clean-up

During the construction period and at final clean-up all areas occupied should be policed regularly for wastes and refuse. At points of burial finished surfaces over compacted fills should be shaped and treated to prevent ponding and erosion. The entire area occupied by the camp and affected by camp activities should be maintained and left in a clean condition.

Pit privies, water-carried waste systems, and burial of body wastes and garbage should not be permitted on a domestic supply watershed.

(b) For use on watersheds not used for domestic supply or where pre-existing conditions already require filtration and disinfection for domestic use.

1. Body Waste

Portable waste containers or sanitary pit privies for small construction camps and crews in upper watersheds should be used. Extreme care must be taken in selecting the point of burial and location of privies. They should be located remotely from any watercourse and on topography not subject to flood, high water table or to erosion from rainfall and snowmelt. Avoid loose (sand and gravel) formation where rapid leaching to a watercourse could occur. Use chemicals for disinfection and fly and odor control. When abandoning pit privies, disinfect the contents of the vault and cover with compacted fill.

For larger construction camps, except in upper watershed areas as discussed previously, water-carried waste systems may be used. The installation of a sub-surface disposal field, for use with septic tanks, should be at a location remote from any watercourse, on relatively flat ground without high water table, free from flooding or erosion by rainfall and snowmelt, and having adequate absorption capacity to receive the effluent without rapid percolation to a watercourse. In lower watersheds where treatment and discharge to streams is acceptable, refer to the appropriate pollution control authority for determination of degree of treatment and final approval.

Liquid wastes from the kitchen and from bath and shower water should be held to a minimum where sub-surface disposal is used.

2. Garbage and other refuse

Garbage and other refuse should be disposed of by sanitary fill method at an approved location or by arrangement with commercial haulers. The location for a sanitary fill should be remote from any watercourse and on land free from flooding, high water table or erosion from rainfall and snowmelt. The particular method of burial should be suitable to the particular site, but in any event the material should be compacted and covered with a minimum of 18 inches compacted fill dirt daily.

3. Clean-up

During the construction period and at final clean-up, all areas occupied shall be policed regularly for waste and refuse. At points of burial finished surfaces over compacted fills should be shaped and treated to prevent ponding and erosion. The entire occupied area should be maintained and left in a clean manner.

2. Railroad Trains in Watersheds

The discharge of wastes from railroad trains is a problem which is particularly acute on domestic water supply watersheds. The modern train, with private compartments and toilets renders any requirement of non-use of facilities while passing through the watershed impractical of complete compliance. Although the railroad industry, through its Joint Committee on Railroad Sanitation, has done considerable research and development work on means of solving this problem, no specific methods have been put into large scale practice. By compari-

son, the airline industry has found and applied a satisfactory method by the use of retention tanks on aircraft which are discharged and serviced at the air terminals. The U. S. Public Health Service Sanitation Manual for Land and Air Conveyances Operating in Interstate Traffic requires that there shall be no discharge from any land or air conveyance of fecal waste, garbage, waste water or other polluting materials while any such conveyance is passing through or over any city or town, a public water supply watershed, the vicinity of a water supply intake in a lake or river, a reservoir from which water supply is derived, or an approved area from which shellfish for domestic consumption are obtained. An attempt at compliance with this requirement includes the locking of common toilet facilities, and informing the patrons and seeking their better judgment in the use of the facilities while passing through the watershed. Obviously, 100 per cent compliance is not obtained. Even if 100 per cent non-use of the facilities while passing through the watershed could be obtained, the problem would not be completely solved. Observers have noted during the winter months that trains passing west over the Cascade Range will carry frozen fecal matter and other wastes on the under parts of the railroad cars and that after descent into lower elevations and warmer temperatures the materials thaw and drop off the train. Bridges have been flashed in an attempt to protect streams, but the flashing will corrode unless adequately protected; also train snow plows will push the accumulated material with snow directly into the stream.

For the immediate future, the following requirements should be met by railroads on public water supply watersheds:

(a) Locking of all toilet facilities while passing through the watershed. (Trains on the Seattle watershed have been required to inform the patrons by public address system just prior to entering the watershed and install mechanical locks for all compartment toilet facilities. These can be operated by train personnel from the train corridor).

(b) Hold all kitchen wastes and other refuse for discharge at terminals.

(c) Periodic inspection of the railroad right-of-way to determine compliance with the above requirements. (In the Seattle watershed policing of the railroad right-of-way by railroad and water personnel immediately after the passing of each train and the removal of all fecal and other solid waste material for disposal at a suitable point is required).

(d) The ultimate solution would seem to be the installation of suitable retention tanks for discharge and servicing at railroad terminals.

3. Agriculture

The following are recommended practices for the protection of watersheds from agricultural activities:

a. Feeding and Watering of Livestock

Feed lots should be located on level ground and drainage from them directed to absorption areas. Covered feed lots with facilities for storing manure until it can be spread on the field are preferred. Feed lots should not be drained into streams, and locating them near streams should be avoided.

Livestock watering places should be located away from streams where possible. Where they are located on streams, controlled access to the stream or watering facility should be provided. Preferably, the stock should water at a pond fed from a stream, but to one side. Such controlled access should hold to the minimum any disturbance to the stream and its banks. Streams should be completely fenced except for planned access to water.

b. Cultivating Land

Since Federal and State agencies have been established for the specific purpose of conserving soil and moisture on farm lands, it does not appear to be necessary to include within the scope of this report any detailed recommendations for practices for erosion control on agricultural lands. By cooperation with the Soil Conservation Service, Agricultural Conservation Program Service, State Extension Services and Soil Conservation Districts, farmers can reduce erosion on farm lands and help maintain the quality of water in streams of the Pacific Northwest.

In addition to erosion, fertilizers applied on saturated soils or at times of flood hazard may be lost to the stream by runoff. This can largely be controlled by appropriate timing of applications.

Certain chemicals, including fertilizers, pesticides, and weedicides, may be washed from the vegetation and soil and enter stream runoff. Care should be exercised in applying chemical sprays and dusts where they may fall on water surfaces or be washed into streams.

c. Irrigation

Nutrients, minerals, and toxic chemicals leached from the soil or from materials applied to the soil and reaching streams through irrigation return flows can and should be controlled. The amount of return flow from the land is best controlled by use of improved irrigation methods for more efficient use of water applied to the land.

Irrigation water should be applied only as needed to maintain a high state of crop production. Only the amount needed to replace the moisture in the root zone of the plants being grown should be applied. This can be accomplished by the use of any method of application if the system is properly designed and good water application practices are followed. Sprinkler irrigation is especially efficient in the use of water.

d. Livestock Wastes

Manure is an ideal fertilizer when preserved and not allowed to leach away before it is applied or after application to the land. The best way to conserve manure is to store it out of the weather in a manure shed until it can be spread. This will avoid leaching of plant food into runoff and stream channels. Avoid spreading on very wet or frozen ground, but spread manure when it can be worked into the soil or during the growing season.

Manure piles during warm weather are breeders of flies. Therefore, schedules should be established for spreading manure on grassland during the summer and fall months, and for storing in piles during the winter months for spreading on cultivated land after the rains.

Dead animals should either be buried well away from streams or taken to a rendering plant for disposal.

e. Domestic Wastes

Septic tanks and subsurface disposal systems or seepage pits should be used for disposal of domestic sewage. All such facilities should be designed and constructed in accordance with the requirements of the Health Department having jurisdiction.

Garbage and other household wastes should be buried or burned but in no case disposed of in drainage ditches or watercourses.

4. The Timber Harvest and Forest Management

a. Access Roads

Specifications included in the preceding recommendations on road and railroad construction should be followed in the location, construction and maintenance of roads used for access to forest areas. It is worth noting that in general the high-standard roads held close to a limited grade demand far more soil disturbance in cuts and fills, and therefore are more of a hazard to streams, than do low-standard roads. Compromise in road standard may be desirable to protect the streams; if a high standard road is decided upon, care must be taken to avoid any further soil disturbance than necessary, and soil stabilization must be made a part of the construction job.

b. Spur Roads

Spur roads used for hauling logs from cutting areas should be located as closely as possible on contour with side ditches provided to carry water to spreading areas, or, where possible, outsloped without ditches. Ditch water should be diverted at frequent intervals onto areas where it can settle out before reaching stream channels.

Construction should take place only during dry weather.

Upon completion of the logging operations in an area all spur roads should be leveled off by filling side ditches and restoring disturbed soil to its original contour. The disturbed area should either be seeded or covered over and secured with a layer of mulch prior to abandonment. 1/

c. Logging

Provisions to protect the water resource must be included during the initial stages of logging management planning and must be followed continuously until logging operations have been completed.

The location of cutting areas and the location of road networks should be correlated in such a manner as to minimize disturbance to the terrain. Cutting boundaries, landings and spur roads can thus be laid out in accordance with the conditions of topography, soil types, and climatic factors in order to take into account the effects of snow accumulations and melt, and to handle drainage so that muddy and turbid waters will be kept out of stream channels. Carefully plan the layout in advance.

The methods of yarding and the equipment used may exert adverse influences on the water resource. Depending on topography and soil condition and type, high-lead cable yarding uphill is usually preferable from the standpoint of protecting stream banks and channels. Tractor yarding should, if possible, be limited to terrains of less than 15 per cent slope in heavy and erodible soils, and should not be used at all on heavy clay soil during wet seasons, on saturated ground, or generally on slopes in excess of 30 per cent.

Only a few turns should be brought in over each skid trail so as to avoid deep gouging, compacting and channelizing.

Skid trails should never run in channels or down channel banks. Channel crossings should be as few as possible and on temporary culverts.

Where it is not possible to lift logs across stream channels with a slack line, temporary measures such as log or metal culverts should be used to prevent excessive turbidity and scouring of the stream banks.

Landings should not be located adjacent to channels and should be in easily drained areas to avoid mud accumulation.

Skid trails should be drained so as to divert water away from landings. It is imperative that cross drains or waterbars be installed in steep abandoned skid trails and spur roads so as to divert drainage concentrations and prevent severe erosion.

Seedings of landings and skid trails to grasses and legumes is favored in the Ponderosa Pine and mixed species types east of the Cascades. For Douglas fir and other types west of the Cascades, seeding or planting of landings and skid trails to forest species is favored.

When logging near streams, trees should be felled uphill away from channels, and slash and debris should be kept out of the watercourse. Logging debris must be removed from stream channels with as little disturbance as possible to the natural bed and banks.

Steep pitches and shallow soil areas immediately adjacent to stream channels should not be logged, if there exists any possibility of slides or erosion directly into the channels.

Buffer strips at least 30 feet wide should be left along channel edges, except in special instances where stream banks are subject to undercutting and sliding, and removal of the weight of the trees may be desirable.

d. Logging Camps and Crews

Logging camps are considered in the same category as construction camps. Due to better access roads and transportation, there is a greater trend in present times toward transporting crews in and out of logging areas each day. This is desirable from a watershed sanitation standpoint and is recommended as regular practice.

When it is absolutely necessary to maintain camps, the same sanitation practices as outlined under Construction Activities (Section 1d above) are to apply. Likewise, the sanitation practices for logging crews shall be the same as outlined under Construction Activities.

Full cooperation with local health authorities and the owner of the water supply affected is essential together with constant vigilance and discipline of the crews in use of the facilities.

e. Forest Fire Control and Prevention

Adequate fire prevention and control measures are of major importance since fire is a constant threat to the timber and water resources of a forested watershed. The low annual burned over area (about one-twentieth of one per cent of total forest area) in favorable years indicates a very effective resource protection program which should be maintained.

Because of the increased silt hazard and the effects of ash in chemical contamination of the water, use of fire on domestic supply watersheds should be avoided wherever possible. If burning is the only practical means of debris disposal, it should be done in such a way and at such times that the organic litter on the soil surface is not destroyed.

1/ See p. 31, U.S. Forest Service Handbook 2533, "Land Treatment Measures".

The adverse influences of slash-burning on domestic supply watersheds and the trend toward increased timber utilization may ultimately reduce the need for widespread burning as a means of slash disposal. A number of timber companies are now utilizing slash in producing saleable products.

On several water supply watersheds alder and willow trees along streams are being eliminated since the falling leaves of these species tend to influence color and perhaps water taste. They are being replaced with spruce or other suitable wet-site species. Insect larvae that drop into streams and affect water quality can be controlled by removing their preferred food plants (alders, willows, shrubs, etc.) from riparian sites.

f. Forest Pest Control

Control of forest insects and fungal diseases and removal of unwanted plants is often done by means of chemical sprays and dusts. Materials to be used, rates of dosage, and methods of application should be approved by State Fish and Game Departments and by State and local public health authorities that may be concerned. Care must always be taken to avoid unnecessary pollution of watercourses and to restrict the treatment to the prescribed area.

5. Grazing

There are various ways to combat range land hazards. The simplest is to close watersheds to grazing. However, with increased pressures for multiple use on most wild lands, the desirability of closure may be questionable. Further, the expense of fencing may provide a serious objection to closure. If the forage can safely be used, it should be used.

Provision of watering troughs, guard fences and masonry casings at springs and seeps will prevent trampling and fouling of the water and keep silt from draining off to the nearest stream.

Holding domestic stock off ranges where the soil is still wet with snowmelt and the cover vegetation is undeveloped will prevent excessive soil compaction. Compacted soil does not take up moisture readily nor does it provide good conditions for plant growth. Rapid runoff of rain water and snowmelt from areas of compacted soil may lead to flash floods, severe erosion, silted stream channels and turbid waters.

A similar problem exists with big game, particularly elk. Large herds following the retreating snow line in spring do extensive damage to the soil and overgraze oncoming new plant growth. Control of game may be accomplished by special hunts to reduce herd sizes. Planting to grow adequate supplies of succulent feed elsewhere may also help.

Sufficient restrictions on grazing in domestic supply watersheds may be gained by fencing off stream channels to keep stock from fouling the water or from breaking down channel banks. Where stock are managed by herders, they can be kept to the benches and upper slopes away from streams. Bridges should be built at regular stock-crossing locations, and springs and seeps developed to furnish water away from streams.

To preserve favorable conditions for absorption of surface water, prevention of soil erosion, and continued production of forage, various measures may be adopted. Increasing the available range area outside the watershed may reduce grazing pressures on the watershed. Increasing the amount and quality of forage by seeding and planting desirable species of grass and shrubs may also help. Improvement of the cover, whether from the forage standpoint or for watershed purposes, probably will require reductions of grazing use at least temporarily. To maintain gains made will require careful management of grazing use thereafter.

Many watershed lands have greatly deteriorated from the effects of continued overgrazing many years ago. In some places the topsoil is gone, leaving a stony and rather impervious clayey subsoil. Plant cover is sparse. These areas are common on ridgetops and upper slopes. Runoff from them is flashy, and causes serious gully and channel erosion below. Rehabilitation is a costly and time-consuming job, but it is possible. 1/ It includes seeding to grass and herbs, and planting to shrubs. To prepare the site to take seed, absorb moisture and afford even fair habitat for growing plants first requires cultivation of the soil. After seeding, mulching to provide shade, to give physical protection against sun and wind and rain, and to furnish organic litter is also often necessary. Finally, fencing to keep stock and game out for several years is required.

Dead animal carcasses should either be buried or taken to a rendering plant for disposal.

6. Mining and Ore Processing

a. Road Construction

Specifications included in Section 1a. above should be followed in the location, construction and maintenance of roads used for access to mines and mining areas. Roads not required after mining operations are discontinued should be drained, mulched and seeded or planted for stabilization before being abandoned.

Outdoor recreation demands clear, clean water

b. Abandoned Mines

Responsibility for cleaning up and protecting areas disturbed during mining operations is that of the owner. The party or parties filing a claim to mineral rights on Federal lands do not receive a "patent" or ownership title to the land until a certain amount of mining has been carried out and the mineral content of the ores prove sufficiently valuable to continue operations. These parties, however, are owners of the mineral rights and all structures built within the claim. Accordingly,

1/ Special water-retarding and soil stabilization measures are described in the U. S. Forest Service Handbook 2533, "Land Treatment Measures".

they are responsible as owners for any conditions created which affect downstream water uses, and are subject to State regulations through the concurrent jurisdiction provisions relating to Federal lands under constitutional law. Some of the states in the Pacific Northwest have laws and regulations governing the abandonment of mines. Unfortunately, however, these laws and regulations were not in effect when some of the early mines were abandoned, and enforcement has not always been successful in eliminating drainage from mines and dumps more recently abandoned. Drainage from abandoned mines and dumps should and can be kept out of watercourses. Before abandoning a strip mine, all overburden should be placed back in the area from which it was removed and covered with a layer of the original or new topsoil. This area should then be seeded with an approved vegetative cover. All openings into underground mines should be sealed in such a manner that will assure that no drainage will come directly from the mine after it is filled with water.

c. Active Mines

Owners of mining claims and owners of land on which mining operations are or are to be undertaken should include in their operation plans or leases the following specifications for control of pollution.

(1) Dredge or Placer Mining

No operations should be allowed in the beds of streams unless the area being worked is dammed off and the stream diverted around the work.

Settling ponds should be constructed to impound and clarify all water used in the mining process before it is returned to the stream. Where possible a closed system wherein no process water is returned to the stream should be used. This should apply both to operations on land and in the bed of streams. Before discharging any impounded water to the stream, it should be clarified sufficiently to assure that the turbidity will not be increased to more than 10 parts per million or other locally established limitation in streams used for public water supply or for salmon, trout or steelhead spawning. In streams used for other purposes the turbidity should be kept below 50 parts per million for normal flow.

Before starting an operation on land, all topsoil should be removed and stockpiled in a convenient safe location. Upon completion of the operation, all ground disturbed during the mining operations should be smoothed over comparable to the natural contour of the ground prior to disturbance. The topsoil removed from the area should be placed on top of the disturbed area and after smoothing, seeded with an approved vegetative cover. 1/

Ground disturbed in the beds of streams should be replaced on meander lines with pool structure conducive to good fish and wildlife habitat and recreational use. 2/

(2) Strip Mining

Prior to the start of a strip mining operation all topsoil should be removed from the area and placed in a convenient location (but where it will not wash into a stream) for future use in rehabilitation of the operating area.

1/ County agricultural agents or State game officers or State and Federal foresters can advise as to suitable species to use.

2/ As recommended by State Fish and Game Departments, or refer to "Fresh-water Fishery Biology", by K. F. Lagler, Second Edition, 1956, pp. 307-320.

All overburden removed from the area should be placed separately from the topsoil in locations where none of the soil will be washed into streams during rains or snowmelt runoff.

During mining operations all water removed from the depression should be pumped into impoundments or allowed to spread on areas covered with vegetation. In no case should any of this water be discharged to the stream directly.

Upon completion of the mining operations, all overburden removed should be spread over the area worked, upon which a layer of topsoil should be placed. The entire area should be seeded with an approved vegetative cover. 1/

In a number of locations in the Pacific Northwest, particularly the side slopes in narrow canyons, it may be impossible to place the topsoil and overburden where it can be returned to the stripped area after removing the ores. In these instances the plan of operation should be submitted to the appropriate pollution control agency for approval prior to the start of any such workings.

(3) Underground Mining

Openings to underground mines should be diked off or otherwise protected to assure that drainage from the mine and working or dump areas near the opening will not flow into streams.

1/ County agricultural agents or State game officers or State and Federal foresters can advise as to suitable species to use.

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All drainage and process water used in the operation should be clarified prior to discharge sufficiently to assure that the turbidity will not be increased to more than 10 parts per million in streams used for public water supply or for salmon, trout or steelhead spawning. In streams used for other purposes the turbidity should be kept below 50 parts per million for normal flows. Drainage water containing chemicals in amounts harmful to any water use should be treated to remove harmful chemicals prior to discharge to a watercourse.

(4) Coal and Ore Processing

Coal and ore processing mills should be located as far away as possible from watercourses and in areas with sufficient land for lagooning or storage of waste tailings. In no case should mills be located where it is necessary to store waste tailings in or immediately adjacent to streams.

Areas used for storage of crushed ore or chemicals used in processing should be surrounded with a dike or housed in watertight structures. Water impounded back of the dike should not be allowed to drain into the watercourse.

Waste process water containing fines and tailings from ore concentration, separation and flotation mills and coal washers should be discharged to settling basins or impoundments. After sedimentation, water flowing from the settling basins should be further treated by filtration, or by other means, if necessary, to remove chemicals harmful to any water use or to assure that the turbidity will not be increased to more than 10 parts per million or other locally established limitation in streams used for public water supply or for salmon, trout or steelhead spawning. In streams used for other purposes the turbidity should be kept below 50 parts per million for normal flows.

Waste tailings removed from settling basins and other dump materials should be placed in areas completely surrounded by a dike or returned to the mine. Drainage water collected back of the dike should not be discharged to the watercourse if it is turbid or contains chemicals harmful to any water uses.

Other type ore processing mills should be equipped with treatment facilities of adequate capacities and of types approved for removal of suspended solids, toxic chemicals, or radioactivity from waste waters. Included in this category are ore precipitation plants, and plants for the extraction of aluminum oxide and uranium compounds.

d. Mining Camp Sanitation

The same principles of sanitation apply to mining camps as are outlined under sanitation for Construction Activities in a preceding section. Permanent camps should not be located on domestic water supply watersheds that now yield high quality water requiring no treatment except chlorination.

7. Recreation Developments

a. Permanent Construction

Permanent camps with permanent buildings, access and facilities provided by governmental agencies or private industry.

(1) Roads

The construction of roads for any purpose poses the same problems. The principles of road building in watersheds for recreational access should be the same as outlined for Roads and Railroads under Construction Activities. Where a domestic water supply is involved the area should be so posted at adequate intervals. Where travel time is particularly long, sanitary pit privies of durable construction located at convenient intervals and remote from watercourses should be provided and maintained by a responsible authority.

(2) Buildings

Buildings should be of durable construction, designed and operated in accordance with good sanitation practice. The location of the building should be such that no adverse effect on the stream will result from sanitary facilities provided.

Design and maintenance should be such as to minimize fire hazard. Bulk fuel oil and gas storage should be separate from buildings for other purposes and where large quantities are involved, emergency catchment basins should be provided to counteract accidental spillage and spread of fire.

(3) Parking Areas

Parking areas for camps and viewpoints should be located in accordance with principles outlined under Construction Activities. Viewpoints should be located preferably at least 100 yards from domestic water supply streams yielding high quality water requiring no treatment except disinfection. Convenient covered containers of durable construction for refuse should be provided and maintained by the responsible authority. When sanitary facilities are provided they should be constructed and maintained as outlined under Construction Activities.

(4) Picnic Grounds

Picnic grounds should be prohibited on domestic water supply watersheds yielding high quality water requiring no treatment except disinfection. On other watersheds the construction of cooking facilities, parking areas and sanitation facilities should follow the principles and objectives outlined under Construction Activities. Facilities for disposal of garbage, refuse and domestic sewage should be designed, constructed and maintained as outlined under Construction activities.

(5) Overnight Camps

Overnight camps should be prohibited on domestic water supply watersheds yielding high quality water requiring no treatment except disinfection. On other watersheds the construction of overnight camps should follow the principles and objectives outlined under Construction Activities, giving particular attention to minimizing fire hazard, erosion, unsanitary conditions and adverse effect on streams. Sanitary facilities provided should be simple, durable and well maintained. Water carriage waste systems should be designed and operated to use a minimum amount of water for disposal. Well maintained portable facilities or sanitary pit privies are preferable where conditions are not suitable for subsurface disposal. Refer to sanitation practices under Construction Activities for detailed principles.

b. Temporary Tent Camps

Temporary tent camps should be prohibited on domestic water supply watersheds yielding high quality water requiring no treatment except disinfection.

Follow same construction principles outlined under Overnight Camps for Permanent Construction. Use portable sanitary facilities or sanitary pit privies of durable construc-

tion. Avoid use of water carriage waste systems; otherwise follow sanitation principles outlined under Construction Activities.

c. Swimming

Swimming and bathing in streams on public water supply watersheds yielding high quality water requiring no treatment except disinfection should be prohibited. On other streams sites for recreational swimming should be located where adequate sanitary facilities for the use of the public and the protection of the stream can be installed.

d. Hunting and Fishing

Hunting and fishing on public water supply watersheds yielding high quality water requiring no treatment except disinfection should be prohibited. Under certain conditions where damage is being inflicted by an over-population of game animals, special hunts can be arranged. The cooperation of health, game and city officials and the hunters is essential to a successful program. Where the problems of over-population justify the special hunt, hunting should be allowed only by special permit and the hunters should be advised in writing as to the nature of the watershed and instructed as to conduct on the watershed with particular emphasis on the proper disposal of garbage, offal, blood, urine, fecal matter and refuse. Overnight camping on the watershed in connection with these special hunts should be prohibited.

e. Application of Pesticides, etc.

Various pesticides or weedicides may need to be applied to public recreation camps, streams, and lakes to reduce mosquito nuisance or to combat excessive growth of aquatic weeds. Care must be used to see that effects of the chemicals used are not spread to a much larger area and that they do not impair downstream uses of the waters that may be affected. Any application should have prior approval both from the State Fish and Game Department and State and local public health authorities that may be concerned.

f. Boats and Boating

Increasing numbers of motor boats on streams and lakes present an increasing hazard from oil and gasoline pollution. In some areas, use of motors may need to be prohibited; in others, restricted to certain areas.

Another problem involved in all boating is the lack of sanitary facilities in locations frequented by boaters. The heavy use of the small islands in the lower Columbia River is a case in point. Where boating use patterns are known or can be anticipated, installations of sanitary facilities to meet the need should be made by the responsible authority. Posting and frequent policing are also desirable. The problem of portable disposable toilets used by many boaters must also be given attention; too often disposal consists of setting them adrift.

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